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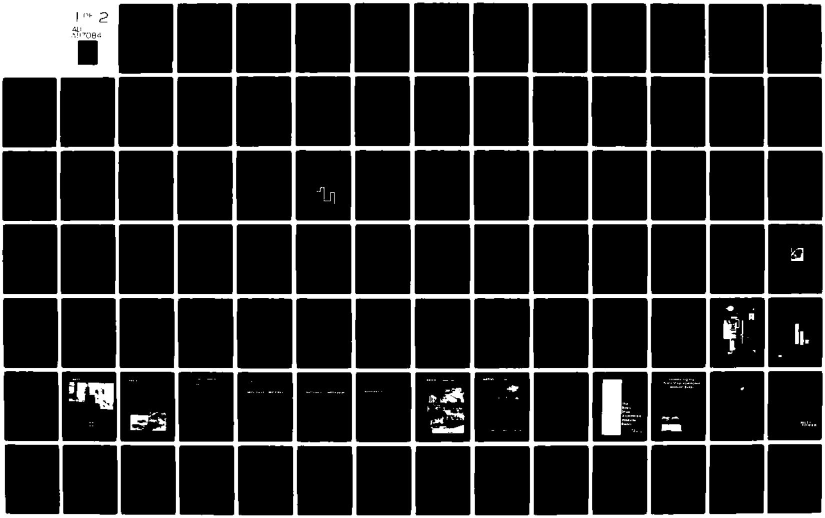

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FINAL
TECHNICAL REPORT

ADVANCED BIO-ENERGY SYSTEMS FOR AIR FORCE INSTALLATIONS

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PREPARED FOR

U.S. ARMY
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This investigation was sponsored by the U S Air Force to determine the potential of using innovative biomass energy conversion technology interface with in-place energy generating hardware to sustain total annual facility energy requirements on a forested airbase. The investigation found that Eglin AFB, FL has high potential for such a system, but that certain components and subsystems require test, evaluation and demonstration in an Air Force base environment before full implementation is possible. The investigation

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found that a biomass energy island system could be achieved through a centralized biomass gasification/combined cycle system to produce 135,000 lb/hr 150 psig steam (saturated) and 27 Mwh/hr electrical power from 1480 green tons of wood chips daily. A phased implementation system is recommended, consisting of separate integrable test and evaluation modules for combined cycle wood gasification and for cogeneration, which would dovetail into an expanded basewide energy self-sufficient system. The investigation did not consider harvestation of base woodlands, which is the subject of a separate effort to define the wood resource aspects of a total biomass self-sufficient system.

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

FOREWORD

This project was sponsored by the Air Force Engineering and Services Laboratory, Headquarters Air Force Engineering and Services Center, Tyndall, Air Force Base, Florida as part of the Air Force Facility Energy Research and Development Program. Program funding is provided by Air Force Systems Command under Program Element 64708F, Project 2054 (Aerospace Facilities Engineering Development), Task 5 (Aerospace Facility Power Systems). The Air Force project officer was Mr. Stephen A. Hathaway. Contract support was provided by the U S Army Facilities Engineering Support Agency (FESA). The FESA project officer was Mr. Jim Thompson.

Appreciation is extented to the following personnel from the Armament Division, Eglin AFB, Florida for their generous assistance throughout this investigation: Mr. Robert Britt, Mr. Arnold Clark, Mr. Stan Reither, Mr. Fred Schultz, Mr. Elwyn Spence, and Mr. Ed Webber.

This technical report will be published jointly by the Air Force Engineering and Services Laboratory as ESL-TR-81-11 and the U S Army Facilities Engineering Support Agency as FESA-T-2110.

ABSTRACT

This investigation was sponsored by the U S Air Force to determine the potential of using innovative biomass energy conversion technology interfacing with in-place energy generating hardware to sustain total annual facility energy requirements on a forested airbase. The investigation found that Eglin Air Force Base, Florida has high potential for such a system, but that certain components and subsystems require test, evaluation and demonstration in an Air Force base environment before full implementation is possible. The investigation found that a biomass energy island system could be achieved through a centralized biomass gasification/combined cycle system to produce 135,000 lb/hr 150 psig steam (saturated) and 27 Mwh/hr electrical power from 1480 green tons of wood chips daily. A phased implementation system is recommended, consisting of separate integrable test and evaluation modules for combined cycle wood gasification and for cogeneration, which would dovetail into an expanded basewide energy self-sufficient system. The investigation did not consider harvestation of base woodlands, which is the subject of a separate effort to define the wood resource aspects of a total biomass self-sufficient system.

EXECUTIVE SUMMARY

The "Energy Crisis" has manifested itself in high energy costs, supply interruptions, inadequate allocation of crude oil, and shortages of products based on crude oil. From a national security standpoint these factors of uncertainty dictate that alternative, renewable, energy sources be exploited.

The Air Force was quick to realize the vulnerability of its installations to fossil fuel interruptions. In June through August 1978 a study was conducted to evaluate the feasibility of using wood grown on selected Air Force installations as the fuel to supply the entire heating requirements of each of those installations, thereby replacing the conventional fossil fuels currently being used. This studv, the Forestry Lands Allocated for Managing Energy, the FLAME study, identified six Air Force installations having the potential for supplying significant portions of their heating energy requirements based on non-merchantable timber grown on their respective installations.

The FLAME concept was subsequently expanded to consider the ability of one installation to meet its total facility energy requirements for an indefinite period of time using its own biomass resource, without external energy supply. This expanded concept is termed a Biomass Energy Island (BEI). Accordingly, this Ultrasystems study extends the FLAME Study with an evaluation of the technical and economic feasibility of providing all facility energy requirements at a selected installation through the energy conversion of locally available biomass resources thereby creating a Biomass Energy Island.

The six installations identified in the FLAME Study were individually evaluated. Of these installations, Eglin Air Force Base was chosen for detailed analysis. Although each installation considered was a reasonably good candidate, Eglin Air Force Base looked the best, overall. Eglin's forest resources were well in excess of those necessary to meet the BEI requirements, as well as the thermal and electrical energy demands being substantial and relatively consistent compared to the other installations.

Four energy systems were conceptually designed for Eglin. The initial systems, using two different technologies, were selected to allow for the demonstration and comparison of separate methods of biomass conversion to energy in full, online operation. Demonstration Module: Option 1, is a gasification, combined cycle system producing 5,000 lbs/hr steam at 150 psig (Sat) and 4 MwH/hr electricity from a fuel wood feedstock of 170 green tons per day. Demonstration Module: Option 2, is a direct combustion, cogeneration system producing 105,000 lbs/hr steam at 150 psig (470^{o}F) and 2 MwH/hr electricity from a fuel wood feedstock of 480 green tons per day. The two initial systems can be implemented sequentially or together.

The third system, a combination of the two initial systems, has capacity sufficient to satisfy the Eglin Air Force Base Main Base complex. The parameters are additive and amount to 110,000 lbs/hr steam at 150 psig and 7 MwH/hr electricity from 650 green tons of wood chips per day.

The fourth energy system, sized to satisfy the BEI concept (supply the facility energy for the entire base), is a centralized biomass gasification, combined cycle system which is an add-on to the Main Base system. The add-on will produce 25,000 lbs/hr at 150 psig and 20 MwH/hr electricity. The combined output will be 135,000 lbs/hr steam at 150 psig and 27 MwH/hr electricity produced from 1,480 green tons of wood chips per day.

The generated energies and the biomass demands of the four systems proposed are summarized in the chart below.

SYSTEM	GTPD*	GTPY* (1000)	ENERGY OUTPUT
DEMONSTRATION MODULE OPTION #1	170	62	4 MWHR/HR 5,000 LB/HR 150 PSIG (SAT) STEAM
DEMONSTRATION MODULE OPTION #2	480	175	3 MWHR/HR 105,000 LB/HR 150 PSIG, 470°F STEAM
MAIN BASE	650	237	7 MWHR/HR 110,000 LB/HR 150 PSIG STEAM
ENTIRE BASE	1,480	540	27 MWHR/HR 135,000 LB/HR 150 PSIG STEAM

*GTPD/GTPY = GREEN (50% MC) TONS PER DAY/PER YEAR

The various systems' economic efficiencies have been estimated and in all cases are relatively favorable. A summary of the energy and dollars saved is shown the the chart below as is the energy/cost (E/C) ratio and the expected payback.

	ELECTRICITY ($.036/KWH)		NATURAL GAS ($2.88/MCF)		WOOD ($15/TON)		NET SAVINGS		ECONOMIC EFFICIENCY	
	MMBTU/YR	$ M	MMBTU/YR	$ M	MMBTU/YR	$ M	MMBTU/YR	$ M	E/C	PAY-BACK (YEAR)
MODULE 1	406,464	29.79	61,132	3.75	527,425	16.89	467,596	16.64	83	11
MODULE 2	304,848	22.34	1,283,778	78.66	1,489,200	47.69	1,588,626	53.31	193	4
MAIN BASE	711,312	52.13	1,344,910	82.40	2,016,625	64.58	2,056,222	69.95	148	6
BEI	2,743,600	201.06	1,650,570	101.13	4,591,700	147.05	4,394,170	155.14	110	8

In summary, each system described appears viable and meets the study criteria of replacing fossil fuel in facility operations. In addition, the two initial modules offer the possibility of a unique demonstration/comparison of two similarly sized, different, conversion technologies. Collectively, the Entire Base system satisfies the Biomass Energy Island concept.

SECTION I

INTRODUCTION

1. BACKGROUND

The "Energy Crisis" that has been experienced over the past few years has created a National awareness of the importance of fossil fuels to the American way of life as well as the country's vulnerability to disruptions and shortages of fuel supplies and the projected increase in fuel prices. In the decade of the seventies, the Organization of Petroleum Exporting Countries (OPEC) benchmark price for crude oil rose from $1.80 per barrel on January 1, 1979, to $30.00 per barrel on December 31, 1979. This constitutes an exhorbitant 1500 percent rise. The problems of energy supply interruptions have not abated in the U.S. since then. Domestic coal production came to a standstill during the 1976 coal miner's strike. In the winter of 1978-79, the Iranian revolution halted that nation's oil exports, creating yet another shortfall in the world oil supply. The ongoing Iraq/Iranian conflict (January 1981) puts the continued supply of Mideast oil in serious jeopardy. Supply interruptions, inadequate allocation of crude oil, and shortages of products based on crude oil have begun to be the rule, rather than the exception. It is this situation that dictates that alternative energy sources be exploited.

The Air Force was quick to realize the vulnerability of its installations to fossil fuel interruptions. In June 1978 they embarked on an in-house study to evaluate the feasibility of using wood grown on Air Force installations as fuel to supply the heating energy requirements of those installations, thereby replacing the conventional fossil fuels currently being used. This study, titled "Forestry Lands Allocated for Managing energy -- FLAME", published in September 1978, identified six Air Force installations that either individually or in combination with one another had the potential for supplying significant portions of their heating energy requirements with non-merchantable timber grown on their respective installations.

This Ultrasystems study is an extension of the FLAME Study, leading to the development and implementation of the Biomass Energy Island (BEI) concept at one of the installations identified in the FLAME Study.

2. OBJECTIVE AND SCOPE

The objective of this study is to evaluate the technical and economic feasibility of providing all peacetime and estimated mobilization level facility energy requirements through energy conversion of biomass available at the installations identified in the FLAME Study, and to select one base for follow-on demonstration of the BEI concept.

This study will also provide preliminary technical and economic data to support a program plan to conduct such a demonstration.

3. SCOPE

As recommended in the FLAME Study, the Air Force facilities to be investigated are:

- Arnold Engineering and Development Center, Tennessee
- Avon Park Range and MacDill Air Force Base, Florida, as a combined effort
- Eglin Air Force Base, Florida
- Tyndall Air Force Base, Florida
- Barksdale Air Force Base, Louisiana

The study explores the technical and economic feasibility of applying current and advanced biomass energy conversion technologies at each of the above installations. Included is an assessment of biomass resources both currently available and potentially available through changes in forest management, alteration of the disposition of currently merchanted timber, and improvement of silvicultural practice to increase the productivity of forested land.

4. SELECTED BASE

Following the preliminary assessment, Eglin Air Force Base was selected as the installation most conducive to the successful demonstration of the BEI concept.

SECTION II

PRELIMINARY SURVEY RESULTS

1. INTRODUCTION

Of the five installations identified in the FLAME Study, two were to be selected for consideration as appropriate for bio-energy technology application. Accordingly, a preliminary survey was carried out to provide data for selection of the two bases seeming most attractive/feasible to become the biomass energy technology users.

2. PRELIMINARY SURVEY METHODOLOGY

Engineers in charge of energy matters--generation and consumptions--were contacted at each of the five bases to be considered. Arnold Engineering and Development Center, TN; Avon Park Range/MacDill Air Force Base, FL; Barksdale Air Force Base, LA; Eglin Air Force Base, FL; and Tyndall Air Force Base, FL. Data on each base's consumption of natural gas, fuel oil, propane, coal, steam and electricity were collected. Wherever conveniently possible, information was provided on capacity, age, average and seasonal loading of boilers at the bases, together with the boilers' energy sources. From these data, the preliminary perspective of the distributions of consumptions of energies at each base could be formulated.

In parallel with the energy data collection, the five base foresters were contacted for information on the biomass resources at the study's five bases. Preliminary figures for present harvesting practice and projected harvesting potential were included in communications received from the bases.

3. DATA COMPARISON AND REVIEW

Each base was analyzed for energy consumption distribution by type of energy; other factors including biomass availability were also considered. Bases were considered individually first, then compared with each other, as appropriate. The main relevant features reviewed are discussed below, base by base.

a. Arnold Engineering and Development Center, TN

Whole base fuel oil and natural gas consumption averages about 68 billion Btu/month, of which about 83% was used in two steam plants, with monthly maximum and minimum consumptions (whole base) at about 101 and 52 billion Btu, respectively.

Arnold's electricity consumption averaged about 432 billion Btu/month (about 52 MwH/hr) with the base's maximum and minimum electricity consumptions at about 589 and 278 billion Btu/month, respectively (about 70 and 33 Mwh/hr, respectively).

Arnold had, itself, performed a study on the replacement of its two major steam producers with a system based on fluidized bed combustion of coal. The engineers associated with energy at the base thought procurement of the system was imminent.

According to the CEEDO FLAME Study, Arnold's available wood supply was sufficient only for about 50% of its energy requirements -- excluding the high electricity demand. Both the likelihood of Arnold converting its large heating energy requirement from natural gas and fuel oil to coal (fluidized bed combustion system) and the deficiency of biomass for meeting energy needs were considered to be of particular note.

Further, Arnold's electricity demand was approximately six times its heating load, on average. Without the demand for a supply of heat to match at least a good proportion of the electricity demand, cogeneration should not be considered. Electricity generation without cogeneration would not be very attractive, economically, for a biomass-based system.

b. Avon Park Range/MacDill AFB

Avon Park Range is coupled with MacDill AFB as these two sites, within 75 miles of one another, have the wood source and an energy demand, respectively. According to the FLAME Study, Avon Park Range could supply 123% of their combined heating needs, however, with the consumers being at separate locations, two sets of biomass energy conversion equipment could not be jsutified. In fact, Avon Park Range uses only about 4% of the energies consumed by that pair of bases.

Considering MacDill AFB only, heating demands ranged between 11 and 27, averaging about 17 billion Btu/month. The electricity demand ranged from 58 to 103, averaging about 80 billion Btu/month (7 to 12 averaging about 10 MwH/hr). Neither of these energy demands was really of large enough capacity to qualify as a good level/scale for demonstration of biomass conversion to energy capability.

Whether small or large in wood requirements, however, environmental and socio-economic constraints have to be met. The MacDill AFB is within the Tampa city limits. Delays or bans on new energy generating facilities in non-industrial areas of cities are presently of frequent incidence, imposed by environmental or community groups. The need for transporting the wood some 75 miles, including part of the way being within the city limits, was decided to be a sufficiently substantial environmental obstacle that the Avon/MacDill option was not considered a preferred site for a biomass conversion facility.

c. Barksdale AFB, LA

According to information included in the "Barksdale AFB Facility Energy Report" of September 1979, Barksdale had recently (July 1978) conformed with DOD requirements and had retrofitted all natural gas-fired

boilers with heat outputs over 5 million Btu/hr with the capability to burn oil. Besides that expensive retrofit, 30-day oil inventory tankage had also been procured.

Although the equipment obtained with this recent expenditure would be made redundant by conversion of the Barksdale AFB to biomass-based energy sources, that aspect should not be a deciding factor. Several other features detracted from the selection of this base as a primary candidate for this study. First, the FLAME Study indicated Barksdale's forestry resources could provide only 43% of the heating energy requirements (10, 33, and 99 billion Btu/month, minimum, average, and maximum, respectively). The 43 percent did not account for the electrical load (6, 8, and 12 MwH/hr, minimum, average, and maximum, respectively). That electrical load would also require biomass for its generation. Not to be overlooked, of course, were the small sizes of both energy consumptions, plus the ten-fold ratio in the case of the maximum to minimum heating energy demands.

d. Eglin AFB, FL

The proportions of Eglin AFB's heating energy demands (28, 58, and 147 billion Btu/month, minimum, average, and maximum, respectively) and electricity usage (182, (23), 225 (27), and 302 (39) billion Btu/month (MwH/hr) minimum, average, and maximum, respectively), were substantial. The electricity ratio of maximum to minimum demands was the lowest of the five bases.

The base's biomass resource was rated at 481% of the heating energy requirement by the FLAME Study. Even including the electrical energy requirement, the biomass resource was well in excess of the maximum level, total Eglin AFB energy requirement. Eglin had, apparently, already initiated actions towards studying installation of wood-fired boilers. This base certainly warranted closer examination.

e. Tyndall AFB, FL

The base's energy engineers indicated that the major proportion of the natural gas consumption occurred on a widely distributed basis, natural gas being fed to hundreds of very small boilers. No consumption breakdown or equipment specifications were said to be available. The expenses of retrofitting a substantial piping network and the heating equipment itself, for distribution of either steam (requiring insulated piping) or low Btu-gas (requiring large diameter headers and distribution piping) would not enhance the image of application of biomass-to-energy at other DOD bases.

When the energy consumption data were examined, the total natural gas and fuel oil consumptions were not found to be of substantial proportions (7, 18, and 46 billion Btu/month for minimum, average, and maximum loads, respectively). The electricity demands stood at 49 (6), 74 (9), and 114 (14) billion Btu/month (MwH/hr) for minimum, average, and maximum uses, respectively. Economies of scale would not be effective.

Although the FLAME Study rated the biomass resource at Tyndall at 120% of heating energy requirements, the average electricity consumption was nearly 35% of the average heating energy use. In summary, then, Tyndall AFB appeared to have very small energy demands, with insufficient biomass resources to meet them.

4. BASE SELECTION

The project Statement of Work initially specified that two bases would be selected for more detailed investigation into the feasibility of deriving their energy requirements from biomass. Demonstration of two different biomass conversion technologies, if feasible, was understood to be desirable for exemplification of the adaptability of biomass for energy generation.

A matrix for selection of the two subject bases was considered, preliminarily. However, when the data were reviewed, the difficulty in trying to weigh the various characteristics for the quantitative selection was found to be unnecessary. For numerous reasons, Eglin AFB was, evidently, the most attractive base for biomass-to-energy applications. These factors are tabulated below:

- Eglin had substantial demands for heating and for electrical energies, so economies of scale would apply.
- The energy applications were various, so more than one biomass conversion technology could be provided at a single base.
- Eglin was the only base with at least adequate biomass resource.
- On a similar foundation, only Eglin AFB appeared to have the biomass resources to fulfill the defined requirements of becoming a BEI (Biomass Energy Island).
- The energy users of Eglin AFB, distributed over a substantial area, but with concentrations of high demand, should allow modular implementation of a system or systems.
- Opportunities for energy efficient systems such as biomass direct combustion/cogeneration and gasification/combined cycle were evident.
- Installation of both of the systems mentioned above, if possible in initial modules of the approximately same energy generation capacity, would allow for accurate, direct comparison of the economics and operating features of these technologies. Such a direct and similarly based comparison had not been performed before.

- Having both technologies at the some location would simplify their being demonstrated to visitors from other prospective biomass-to-energy users of the DOD.

These points, providing the main thrust in Ultrasystems' recommendation to the Army and Air Force Technical Project Officers, led to agreement to permit a single base, namely Eglin, to be considered for application of at least two biomass-to-energy conversion facilities.

SECTION III

ANALYSIS OF SELECTED BASE

1. INTRODUCTION

Based on the selection of Eglin AFB as the location for the preliminary study of the feasibility of biomass-to-energy systems, a visit was made to that base. The bulk of the data on Eglin's energy consumptions and biomass resources was acquired on this visit; additional data were made available by Eglin personnel by telephone or mail as their needs became more evident.

2. ENERGY DEMANDS

a. Present Energy Supplies and Demands

The major concentration of energy consumption occurs at the region of Eglin termed the Main Base. The breakdown on energy users was presented in Eglin's report entitled "ADTC Energy Reduction and Analysis Plan" of June 1, 1977. These values, most of which were estimated by the base's Armaments Development and Test Center who performed the study, are presented in Table 1.

Fourteen boilers of various ages (11 to 30 years) rated from 2.7 to 5 million Btu/hr are fired with natural gas and are located within 900 feet of a central point on the Main Base. (See Figure 1.) A centralized boiler rated at about 50 million Btu/hr could satisfy all of these distributed steam demands. Further, a centralized boiler of 100,000 lbs/hr of 150 psig saturated steam capacity was said to be suitable for supplying minimum demands all year, including space heating in winter and planned condensation coolers in summer. The equipment testing Thermal Laboratory, part of the Main Base, was known to have high, intermittent energy demands for heating and cooling.

Several other locations could use a central boiler to supply energy to several single users now using individual boilers. Eglin's boiler data are shown in Appendix A.

In summary, the Eglin energy demands are shown below:

		ELECTRICITY MwH/hr	NATURAL GAS, ETC.(1) (MBtu/hr)
Entire Eglin Base	Min.	23 (Nov)	40 (Aug)
	Av.	27	81
	Max.	39 (Jul)	205 (Jan)
Eglin Main Base	Min.	10	17
	Av.	12	34
	Max.	17	86

(1) Includes heat equivalents of fuel oil and propane consumed.

	Electricity(%)	Natural Gas, etc.(%)[1]
Hospital	6	4
Housing	24	31
Shopping	2	3
E. Ranges	1	1
W. Ranges	1	-
Field #6	1	1
Field #3	2	3
Ordnance Area	1	6
Main Base	43	42
33rd TFW	2	1
Federal Prison	1	-
Halburt Main Base	9	3
Halburt Housing	4	4
Other (misc.)	3	1
	100	100
Total Base Consumption	232,000 (Mwhr/yr)	730×10^9 (Btu/yr)

(1) Includes heat equivalents of propane and fuel oil consumed.

TABLE 1. Distribution of Energy Consumption at Eglin Air Force Base

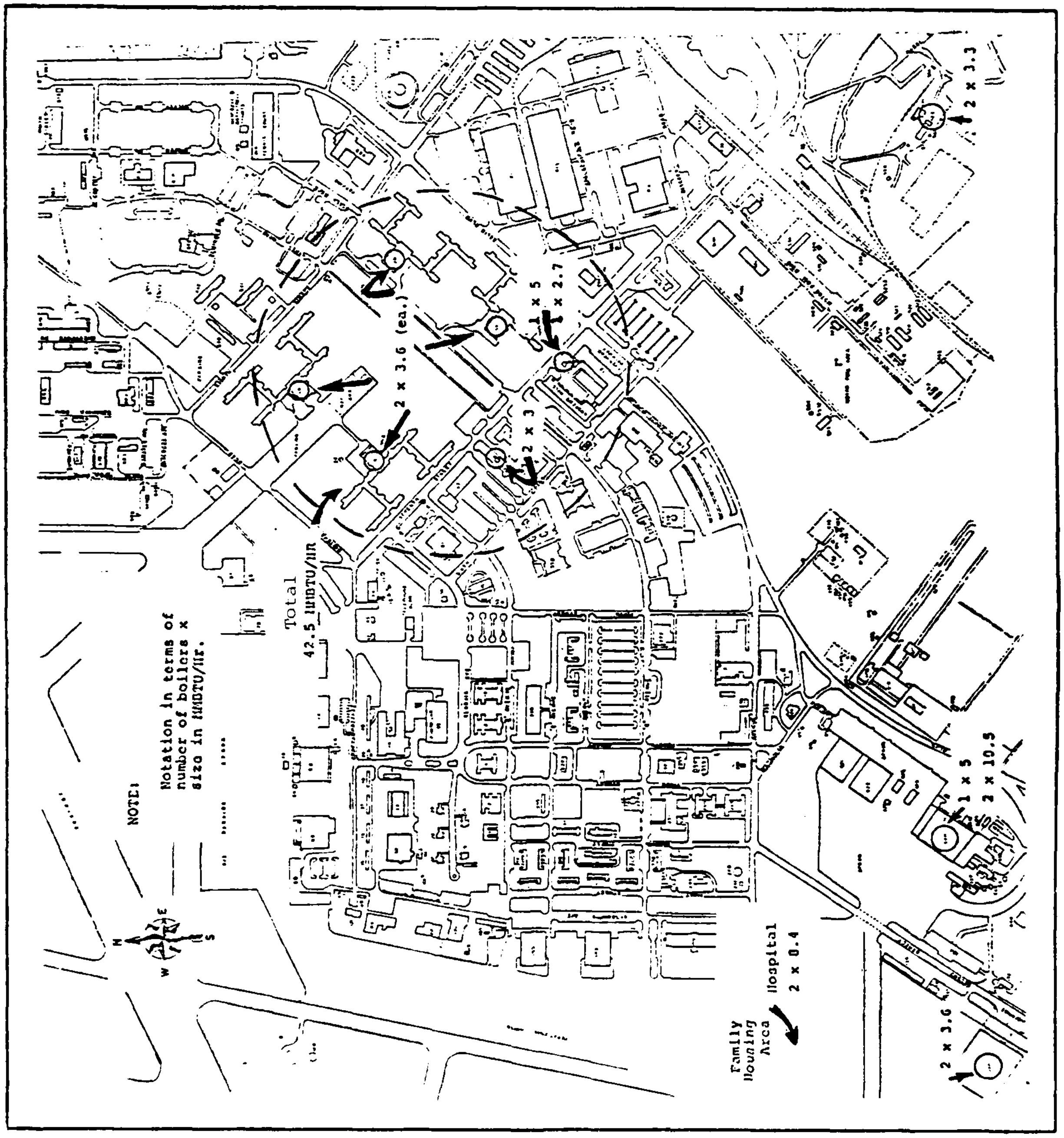

FIGURE 1. Location of Boiler Plants Main Base, Eglin Air Force Base

Electricity is supplied by Gulf Power at about 3.7¢ per Kwh, said in July 1980 which is about to be increased by 65%. Annual electricity consumption costs Eglin AFB about $8.5 - 9 million.

Natural gas is supplied by Okaloosa Gas at about $2.88 per 1000 cubic feet, said in July 1980 to be about to be increased by $3.00. Annual natural gas consumption costs Eglin AFB about $1.5 million.

3. BIOMASS RESOURCE

The base forester and some of his staff provided the following data to Ultrasystems at Eglin AFB. The current timber output of 12 million board feet (80,000 green tons)* is held at that level by directive of the base, itself. More than triple that amount (39.5 million board feet or about 264,000 green tons) could be made available without adjustment of the present forest management. Some of Eglin's timber customers are totally dependent on that source of supply. Boardwood was said to be selling at $15 per ton on the stump, pulpwood at $2 per ton, with transport of the wood estimated at 7¢ per ton-mile.

If intensified forest management were to be applied to the acreage presently being forested, about 103 million board feet (690,000 green tons) could be harvested each year, according to a "Model Forest Management Plan" developed by the Eglin AFB Forester.

Residues, as would accompany each of the above quantities, are estimated (by the USDA Forest Service Research Note SE-263 on residues) to be approximately 22% of the weight of the harvested timber.

At the extreme, if all of the forested acreage, some 407,000 according to the USDA Forest Service report **, were harvested, about 250 million board feet per year plus the associated residues could be made available, totalling about 2,033,000 green tons. That figure is reasonably conservative as Ultrasystems' Energy Plantation concept uses only twice the 2.5 green tons per acre-year growth, the present growth rate, whereas the Vanguard report indicates that a factor of 2.9 could be obtained.

For convenient reference, the green ton values for these various harvesting and forest management combinations are shown in Table 2.

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* Approximately 6.7 green tons (50% M.C.) of pine per 1000 board feet.

** "Vanguard for the Environment: An action program to harness the full resource capabilities of Eglin AFB"

FOREST MANAGEMENT INTENSITY / APPLICATIONS OF PRODUCTS HARVESTED	RESIDUES FOR FUEL, ONLY, ALL COMMERCIAL MATERIALS HARVESTED BEING MARKETED A	OTHER THAN MAINTAINING CURRENT MARKET SIZE, ALL RESIDUES AND COMMERCIAL MATERIALS USED FOR FUEL B	ALL FOREST RESIDUES AND COMMERCIAL MATERIALS TO FUEL C
1. CURRENT LEVELS OF FOREST MANAGEMENT AND HARVESTING	18	18	98
2. CURRENT LEVELS OF FOREST MANAGEMENT, BUT HARVESTING EXPANDED TO APPROACH ANNUAL GROWTH IN PRESENTLY HARVESTED ACREAGE	58	244	324
3. EXPANDED HARVESTING WITH INTENSIFIED MANAGEMENT	152	762	842
4 ENERGY PLANTATIONS	N/A	1950	2030

TABLE 2. Fuel Wood Resources
(Thousand Green Tons/Yr)

4. SYSTEM DESCRIPTIONS

a. Introduction

The thermal efficiencies, hence the quantities of biomass feedstock required, differ for the conversion processes to be considered. The phase/forms of the energies to be generated also vary and can be utilized directly or indirectly, perhaps requiring retrofitting to benefit from the form of energy to be made available. Obviously, then, the economics also will vary. This subsection and the next one review these features, presenting the reasoning for the selection of the systems recommended.

The combination of systems offered here is a first iteration and, unless the optimum has happened to have been selected, the biomass requirements should be less than the values calculated, or the energy output should be greater for the same biomass feed. Optimums of wood feed consumed and energy produced can be determined in a detailed "follow-on analysis", as anticipated in the Statement of Work prepared for this project.

b. Process Selection Overview

Founded on the data obtained from Eglin, the following biomass-to-energy conversion systems were formulated at first interation. Detailed analysis will permit optimization of the systems. Two processes, commercially proven, are proposed, namely biomass direct combustion for cogeneration and biomass gasification for combined cycle systems.

The first energy level to be used as a guideline was 100,000 lbs/hr of 150 psig saturated steam, said to be usable on the Main Base throughout the year. A first demonstration module could be developed based on this quantity and form of energy. Direct combustion could generate steam, but substantially greater benefit, considering the Eglin AFB electricity expenditure, would be derived from cogeneration. The 100,000 lbs/hr of 150 psig steam could be the exhaust from a back-pressure steam turbine generator. To avoid the substantial expenses of materials and supervision for a high pressure boiler, a 700 psig, 750^{o} F steam producing boiler-furnace is to be considered. A cogeneration system of these specifications would be based on 105,000 lbs/hr of 150 psig steam exhaust (with 110^{o} F superheat) and about 3 MwH/hr electricity could be generated

For direct comparison with the cogeneration system, a combined cycle system of approximately the same electrical output is proposed, namely 4 MwH/hr. Additional 150 psig saturated steam can be produced from the diesel engine or gas turbine generator exhaust. This quantity of steam is conservatively estimated at 5,000 lbs/hr, and can be more precisely determined in a detailed study.

As already mentioned, some retrofitting of the energy-consuming equipment of the Main Base is anticipated to accommodate the energy being supplied by a centralized boiler system. Since the exact applications, hence the energy transfer efficiencies, of the steam energy are not specifically defined, the products of the proposed demonstration modules (7 MwH/hr electricity plus 110,000 lbs/hr 150 psig steam) and the Main Base demands (12 MwH/hr electricity plus 34 million Btu/hr natural gas equivalent, on average) cannot be precisely matched. The unit sizes were selected to closely approach the Main Base total energy demand.

All the electricity substations within the Eglin AFB are owned and operated by Eglin. Thus, any surplus electricity generated at the Main Base can easily be dispatched to other locations on the Eglin AFB. Alternatively, if the Main Base has greater demand than can be supplied by its own energy generation systems, spare capacity at other system(s) on the Eglin AFB can supplement the Main Base's generating capacity.

The balance of the entire Eglin Base's (average) energy load would be about 20 MwH/hr of electricity. A gasification combined cycle system is proposed for this function, providing a small amount of steam generation (about 25,000 lbs/hr, 150 psig steam) as a small surplus for contingencies.

The Eglin AFB energy demands, shown in part 2 of this section, indicate that the average loads appear to be reasonable design levels; the electricity and natural gas demand peaks are at different times of the year. The cogeneration and combined cycle systems proposed allow for interchange of duties depending on the energy demand distribution, as well as for good turndown capability, as required. Specifics on features of the two technologies proposed are given in the following section.

c. Staged System Implementation

As mentioned above, the specific sizes of the various units to be employed should be optimized in a detailed follow-on analysis. The staged implementation of systems could, perhaps, also be adjusted, but the broad procedure recommended presents a logical, structured approach for Eglin AFB to become a biomass-to-energy base.

No single Eglin location consumes more energy than all the rest of the base put together, but the Main Base is a very large user of electricity and natural gas. To allow time for planning and, as may be required, retrofitting for change of the form of energy to be consumed at the distributed locations on Eglin AFB, two central systems are suggested to meet Main Base energy demands. Further, these systems are modules of different technologies which can be economically and technically compared and/or expanded in size and application. If extensive electrification of the Eglin AFB, particularly in the areas remote from the Main Base, were to be carried out, the generation of all electricity could take place in a single location. The electricity substations and distribution systems belonging to Eglin AFB facilitate this approach.

The two initial systems for the Main Base are termed Demonstration Modules in this report. This term was selected, not because the technologies have not been commercially proven--they both have been--but for the DOD to have two units (at the same location) able to demonstrate applications and comparisons of biomass conversion to energy, in full, online operation.

The two Demonstration Modules could be implemented sequentially, or together. In combination, they will be of capacity sufficient to meet the needs of the Main Base. Additional energy generation capacity, either distributed or decentralized, will be required to meet the entire Eglin AFB energy needs. Each of these cases is discussed below.

d. Demonstration Modules

(1) Option 1: Biomass Gasification and Combined Cycle

Gasification of biomass has been carried out with limited success on many occasions for a long time, providing the technology with an unattractive image. However, biomass gasification is presently being

efficiently applied commercially, with systems incorporating electricity generation and permitting combined cycle energy efficiency. Information on a particularly economical and reliable system in current industrial use is presented in Appendix B, Gasification and Combined Cycle Literature.

In broad terms, the proposed system consists of a gasifier into which wood chips and air are fed. The low Btu gas generated is cleaned and fed to either a diesel engine generator (with about 10% supplementary diesel fuel) or to a gas turbine generator system. The steam which can be produced from the generator exhaust can be at low pressure for use in that condition, or can be a lesser quantity of steam at higher pressure for feeding to a back-pressure steam turbine generator. The latter, a cogeneration system, will generate electricity and make process steam available. A block diagram of the combined cycle system is shown in Figure 2. A preliminary estimate of the biomass required for generation of 4 MwH/hr and (at least) 5000 lbs/hr 150 psig saturated steam is 170 green tons of wood chips per day.

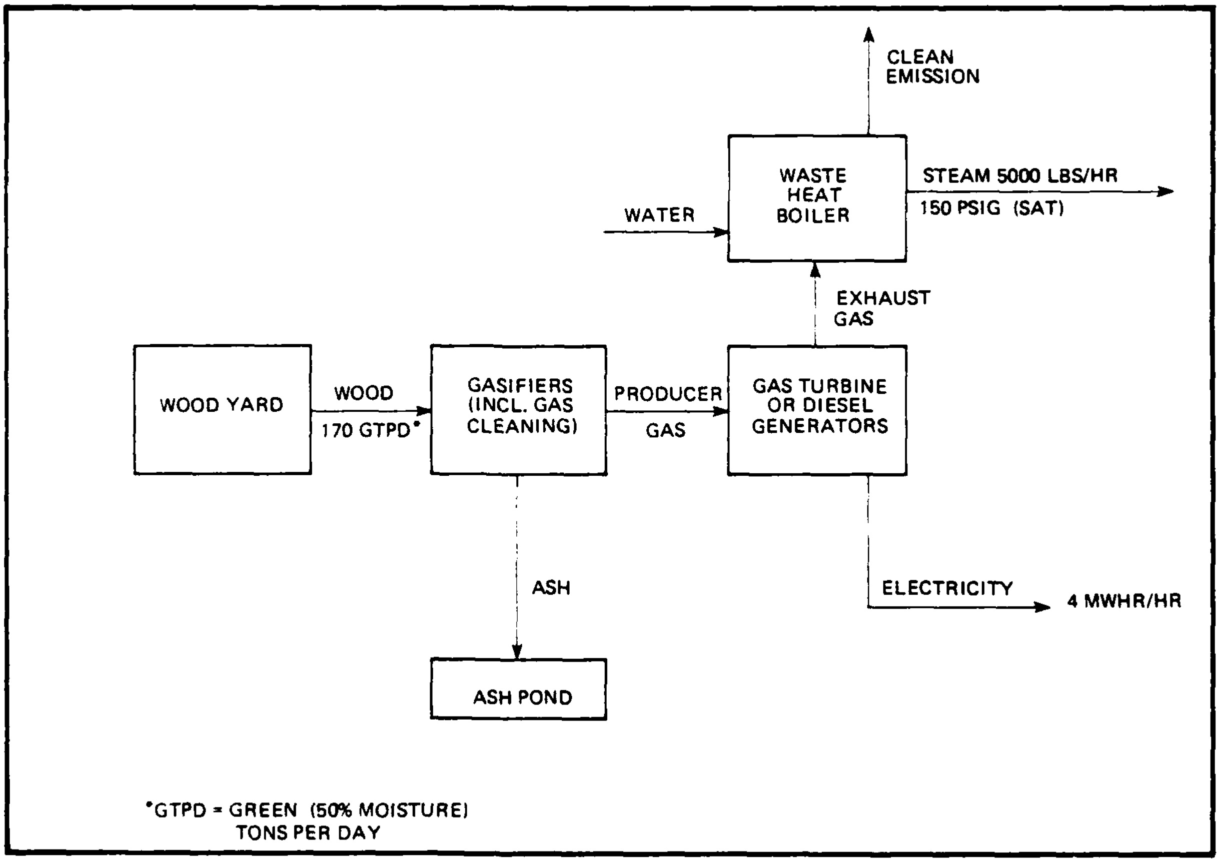

FIGURE 2. Demonstration Module: Option 1 Gasification (Combined Cycle) System

(2) Option 2: Biomass Direct Combustion and Cogeneration

Furnace-boiler systems based on biomass fuel are well known and commercially proven. A cogeneration system consists of the steam produced being fed to a back-pressure steam turbine generator. Besides electricity being generated, a back pressure turbine provides exhaust steam at desired pressure, available for process heating.

The overall system thermal efficiency is much greater for a back-pressure steam turbine as compared with a "condensing" turbine. The latter requires less steam per Kw generated as against a back-pressure turbine, but the latent heat of vaporization is lost from the exhaust vapor; a condensing turbine does exhaust very low pressure steam, not condensate. Provided there is a condensing use for the exhaust steam from a back-pressure turbine, the overall system thermal efficiency is always greater than that of a condensing turbine. Approximately 60% of the produced steam's heat content is discarded with a condensing turbine. Hence, cogeneration is the system proposed for Eglin AFB.

As compared with the combined cycle system, the cogeneration system has the slightly higher overall thermal efficiency, but the exhaust steam from the back-pressure turbine must be used to achieve this higher efficiency. If the use for steam should drop or be eliminated, the combined cycle system can reduce or eliminate its production of steam from its exhaust gases with much less loss of efficiency than could the cogeneration system, which would have to condense its exhaust steam. Even if that steam were exhausted at as low a pressure as 4 inches of mercury, the latent heat of vaporization would be lost.

For generation of 3 MwH/hr electricity with 105,000 lbs/hr of 150 psig (110^{o} F superheat) steam being exhausted, a preliminary estimate is that 480 green tons of wood chips per day would be required. A system block diagram of a cogeneration system is shown in Figure 3.

e. Main Base Biomass Facility

The biomass facility proposed for the Main Base is to consist of both options of the Demonstration Modules. This system will provide operating flexibility, particularly regarding turndown. Whereas the economic operation of a cogeneration unit is largely reliant on the level of the steam demand, a gasifier system can easily operate at 30% of design load. With inclusion of certain features in the instrumentation and equipment design, the gasifier based electricity generation unit can successfully operate at low turndowns.

Other useful features of the two biomass systems being at the Main Base include having to provide only a single biomass inventory location and non-duplicative materials (wood chips and ash) handling systems. If the option of generation of high pressure steam from the gas

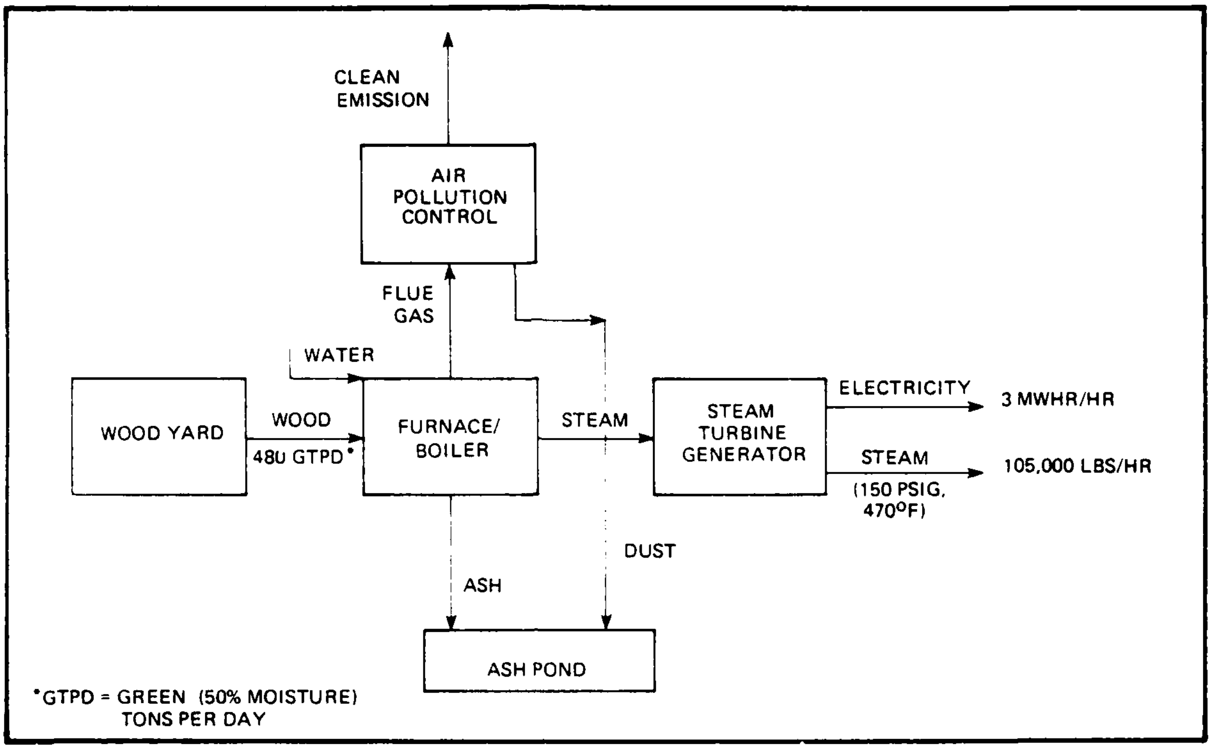

FIGURE 3. Demonstration Module: Option 2 Direct Combustion (Cogeneration) System

turbine/diesel generator exhaust is selected, that steam could be combined with the direct combustion steam for feeding to that steam turbine generator. An additional, small steam turbine generator would not then be needed specifically for the combined cycle system.

Thus, for the Main Base, the combined systems shown in Figures 2 and 3 will generate a total of 7MwH/hr and 110,000 lbs/hr (at least) 150 psig steam. Preliminary estimates indicate that 650 green tons of wood chips will be required per day as feed for these units.

f. Biomass-to-Energy for the Entire Eglin AFB

Depending on the findings of the follow-on detailed analysis, a centralized system or distributed facilities could be appropriate for providing the balance of the energy needs for the entire Eglin AFB. A centralized biomass gasification combined cycle system to generate another 20 MwH/hr and to produce another 25,000 lbs/hr (at least) 150 psig saturated steam is recommended. The preliminary estimate of feed required for that system is 830 tons of green wood chips per day. A block diagram of this system is shown in Figure 4.

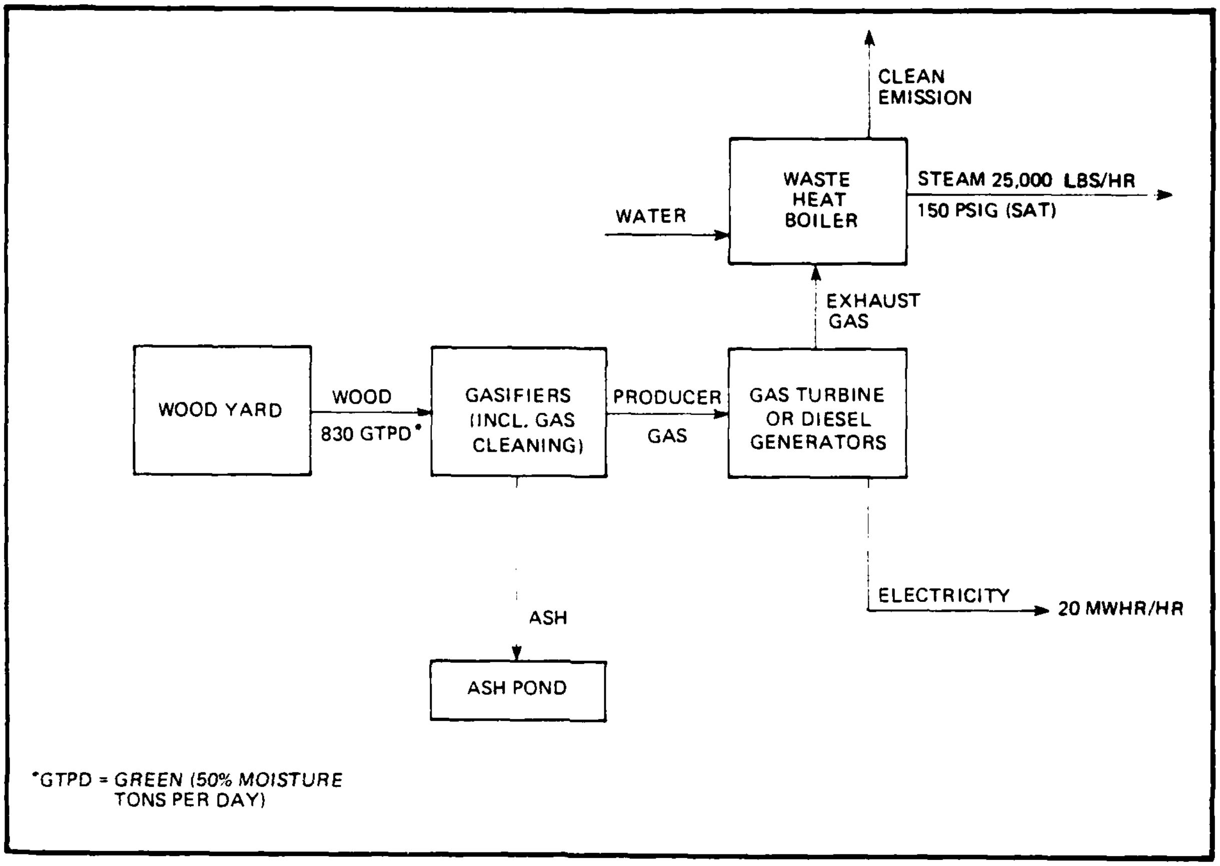

FIGURE 4. Biomass-to-Energy System: Entire Base

5. CORRELATING BIOMASS RESOURCES WITH PROPOSED ENERGY GENERATION SYSTEMS

The energies generated and the biomass feed requirements for each system proposed are shown in Table 3. In part 2 of this section, various possible levels of biomass availability, depending upon the harvesting, the marketing, and, most of all, the forest management levels, are presented. These biomass levels are summarized in Table 2. Resource levels are correlated with the various energy generation systems in Table 3. Compatible combinations of supply and demand levels are indicated in Table 4.

SYSTEM	GTPD*	GTPY* (1000)	ENERGY OUTPUT
DEMONSTRATION MODULE OPTION #1	170	62	4 MWHR/HR 5,000 LB/HR 150 PSIG (SAT) STEAM
DEMONSTRATION MODULE OPTION #2	480	175	3 MWHR/HR 105,000 LB/HR 150 PSIG, 470°F STEAM
MAIN BASE	650	237	7 MWHR/HR 110,000 LB/HR 150 PSIG STEAM
ENT:RE BASE	1,480	540	27 MWHR/HR 135,000 LB/HR 150 PSIG STEAM

*GTPD/GTPY = GREEN (50% MC) TONS PER DAY/PER YEAR

TABLE 3. Proposed System Biomass Demands and Generated Energies

DEMAND LEVELS \ SUPPLY LEVELS	1		2			3			4
	A&B	C	A	B	C	A	B	C	B&C
DEMONSTRATION MODULE OPTION #1 (62,000 GTPY)	NO	YES	NO	YES	YES	YES	YES	YES	YES
DEMONSTRATION MODULE OPTION #2 (175,000 GTPY)	NO	NO	NO	YES	YES	NO	YES	YES	YES
MAIN BASE (237,000 GTPY)	NO	NO	NO	YES	YES	NO	YES	YES	YES
ENTIRE BASE (540,000 GTPY)							YES	YES	YES

TABLE 4. Correlation of Resource Demands with Availability

6. ECONOMIC ESTIMATES

a. Introduction

The following sections provide preliminary, order of magnitude estimates of installed equipment costs and operating costs for the proposed biomass to energy conversion systems.

The cost values presented are conservative and should prove to be lower with closer investigation. Unless, by chance, the optimum systems were selected at this first iteration, improved costs and fuel consumptions should be possible. More precise economic data can only be obtained after the detailed follow-on analysis (specified in the Statement of Work) has optimized the energy demand data and system supply options.

The cost effectiveness and the quantity and values of fuels saved are also reviewed for each system proposed. In each case, energy savings will be realized in reduced electricity and natural gas consumptions. These energy savings will be offset by the energy in the wood consumed. Depending on the efficiency of the conversion processes, some of the proposed systems yield net energy gains and some yield net energy losses. Present DOD/DOE guidance, however, provides credit for use of a renewable fuel (solar, biomass, hydropower, geothermal and wind) which makes wood fuel an essentially free energy from a reporting standpoint. This approach may change, but for this analysis the current prevailing guidance will be used. Accordingly, the E/C ratio calculations do not consider wood energy as offset against electricity and natural gas energy savings.

Costs, on the other hand, have a real impact on the budget and cannot be ignored. Net cost savings from the replacement of electricity and natural gas by wood are calculated based on delivered fuel wood cost of $15 per green ton, and on electricity and natural gas costs of 3.6¢ per Kwh and $2.88 per thousand cubic feet, respectively. The total benefit calculation, the discounted benefit/cost ratio and the payback period are based on the net energy cost. The collective bases/assumptions used in making the economic estimates and cost effectiveness analysis are listed below:

- Capital cost were provided by equipment vendors and construction companies.
- Design costs were taken as 6% of installed capital costs.
- Inflation was applied for construction to commence at the beginning of FY84, to take one year, and escalated to the middle of the construction period.
- Labor was taken as 3% of installed capital costs.

- Materials were taken as 4% of installed capital costs.

- Eglin electricity and natural gas costs were taken at 3.6¢/Kwh and $2.88/MCF, respectively.

- In accordance with prevailing DOD guidance, energy from renewable sources (e.g., solar, biomass, hydropower) was taken as "free" energy for reporting purposes.

- Fuel wood cost was estimated at $15/green ton, delivered, based on present Eglin wood harvesting costs, profit and overhead.

- Unit efficiencies used were approximately 80% for gasifiers, 70% for boilers, and 70% for turbine generators.

- Methods for energy/cost balances were as per ECIP guidance memorandum.

b. Demonstration Module: Option 1
(Gasification, Combined Cycle System)

(1) Capital (Installed Equipment) and Operating Costs

A system to gasify wood for production of 4 Mwh/hr of electricity could take the form of either a single gasifier costing about $525,000, with the possibility of a 100% standby unit--doubling the cost--or three units half of that size, costing about $325,000 each, allowing 50% standby capacity. The three unit system will allow better flexibility for maintenance and turndown. The costs quoted include installation.

Mention has been made of diesel generators and gas turbine generators for low Btu gas conversion to electricity. Though the former is the more readily available of the two options, the diesel generator does require a supplementary feed of diesel fuel amounting to about 10% of the unit's energy input requirement. Vendors of gas turbines which have been modified to operate on low Btu gas (rather than natural gas) have been found. Such units are presently operating and are lower in capital and operating costs than are diesel generators. In this study, gas turbines are recommended for use.

The boiler for recovery of heat from the turbine exhaust gases could be one of the base's existing boilers, but the feasibility of this approach would have to be examined in the follow-on analysis. If a new waste heat recovery boiler to produce 5,000 lbs/hr of 150 psig saturated steam were required, its installed cost, including flue gas stack and associated equipment, should not exceed $300,000.

Two 2.5 Mwh/hr skid-mounted gas turbine generators cost about $300,000 each. The installation is not expected to exceed $200,000 each.

The surplus capacity (above 4 Mwh/hr) could be used if producer gas were available. A cost summary is shown below:

	ESTIMATED INSTALLED COST
3 Gasifiers (each 50% capacity, including environmental control equipment)	\$ 1,000,000
2 Gas turbine generators, each 62% capacity	2,000,000
Waste heat boiler (including flue gas stack and associated equipment)	300,000
Miscellaneous (electric gear, utility facilities)	900,000
Contingency (10%)	400,000
TOTAL INSTALLED COST	\$ 4,600,000
Annual Operating Cost (Excluding wood)	\$ 322,000
Daily wood requirement of 170 tons at \$15 per green ton delivered	\$ 340,000/yr (90% steam factor)

Facility Output: 4 Mwh/hr electricity and 5,000 lbs/hr 150 psig saturated steam.

(2) Economic Analysis/Cost Effectiveness

The costs expressed in the preceding system's cost description represent estimated costs at the beginning of calendar year 1981. In accordance with the assumptions of paragraph 6.a. and the guidance given OASD (MRA&L) memorandum dated 21 October 1977, subject: Energy Conservation Investment Program (ECIP) Guidance, the following factors have been applied to those base figures for the economic analysis:

- o Capital costs have been escalated 6% per year for 3 1/2 years. Thus the current working estimate (CWE) is:

$$\begin{aligned} \text{CWE} &= \text{Base Capital Cost} \times (1.06^3 \times 1.03) \\ &= \text{Base Capital Cost} \times 1.23 \end{aligned}$$

- o Design cost is taken as 6% of Base Capital Cost and escalated one year at 6%. Thus:

$$\text{Design} = (\text{Base Capital Cost} \times .06) \times 1.06$$

- o Labor costs are taken as 3% of Base Capital Cost and escalated 6% per year for 3 1/2 years.

$$\text{Labor} = (\text{Base Capital Cost} \times .03) \times 1.23$$

- o Material costs are taken as 4% of Base Capital Cost and escalated 6% per year for 3 1/2 years. Thus:

$$\text{Material Cost} = (\text{Base Capital Cost} \times .04) \times 1.23$$

These factors have been applied to each system's economic analysis and account for the difference between the base figures shown in each system's cost description and the figures used in its economic analysis summary.

The economic analysis summary for the gasification, combined cycle system is shown in Table 5. In brief, this option will result in:

o A project capital cost of:	$5,660,000
o Annual energy savings of:	467,596 MBtu
o An E/C ratio of (MBtu/$K):	82.6
o Discounted Benefit/Cost ratio of:	2.2
o Annual dollar savings of:	$520,000
o A payback period of:	11 years

c. Demonstration Module: Option 2
(Direct Combustion, Cogeneration)

(1) Capital (Installed Equipment) and Operating Costs

Discussions with equipment vendors concerning steam turbine-electricity generator equipment revealed that 3 MwH/hr of electricity could be generated from boiler steam production of about 105,000 lbs/hr of 700 psig, 750° F saturated steam with 150 psig exhaust steam.

	($K)	($K)
COSTS		
1. Non-recurring Initial Capital Costs		
a. CWE	$ 5,660	
b. Design	$ 293	
c. Total		$ 5,953
BENEFITS		
2. Recurring Benefit/Cost Differential Other than Energy		
a. Annual Labor Increase	$ 170/yr	
b. Annual Material Increase	$ 226/yr	
c. Other Annual Increase	-	
d. Total Costs	$ 396/yr	
e. 10% Discount Factor	8.933	
f. Discounted Recurring Cost (d x e)		$ 3,537
3. Recurring Energy Benefit/Costs		
a. Type of Fuel: ELECTRICITY		
(1) Annual Energy Decrease	406,646 MBtu	
(2) Cost per MBtu (Actual $)	$ 4.77/MBtu	
(3) Annual Dollar Decrease	$ 1,939/yr	
(4) Differential Escalation Rate (7%) Factor	15.363	
(5) Discounted Dollar Decrease	$ 29,786	
b. Type of Fuel: NATURAL GAS		
(1) Annual Energy Decrease	61,132 MBtu	
(2) Cost per MBtu (Actual $)	$ 3.66/MBtu	
(3) Annual Dollar Decrease	$ 224/yr	
(4) Differential Escalation Rate (8%) Factor	16.740	
(5) Discounted Dollar Decrease	$ 3,745	
c. Type of Fuel: WOOD		
(1) Annual Energy Increase	527,425 MBtu	
(2) Cost of MBtu (Actual $)	$ 2.46/MBtu	
(3) Annual Dollar Increase	$ 1,297/yr	
(4) Differential Escalation Rate (5%) Factor	13.018	
(5) Discounted Dollar Increase	$ 16,890	
d. Discounted Energy Benefits (3a(5) + 3b(5) - 3c(5))		$ 16,641
4. Total Benefits (3d - 2f)		$ 13,104
5. Discounted Benefit/Cost Ratio (Line 4 ÷ Line 1c)		2.2
6. Total Annual Energy Savings (3a(1) + 3b(1))		467,596 MBtu
7. E/C Ratio (Line 6 ÷ 1a/1000)		82.6
8. Annual $ Savings (3a(3) + 3b(3) - 3c(3) - 2d)		$ 520/yr
9. Payback Period (Line 1a - Salvage) ÷ Line 8		11 yrs.

TABLE 5. Economic Analysis Summary
Demonstration Module: Option 1

The tubular boiler would have a furnace with an inclined, water cooled grate. The furnace should be fitted for oil or gas combustion as standby in case of fuel feed problems such as, say, feed blockages or a very high feed moisture content. (Preferred fuel size would be 2" hogged wood chips.)

The boiler-furnace system price includes an air heater, dust collection, FD (forced draft) and ID (induced draft) fans, walkways, ladders, structural steel, and combustion controls. The price would be about $1.8 million for equipment and about $0.9 million for installation. Alternatively, a shop fabricated and assembled system is available in modules of a nominal 50,000 lbs/hr of steam generation. The cost of

field erection is much reduced. Allowing for 50% spare capacity, three installed modules would cost about $3 million total.

The stack for dispersion of the combustion fumes would be about 50 feet high and, together with a bag filter would cost about $400,000 installed.

The steam turbine-electricity generator system would consist of three 1.5 MwH/hr generation units including their lube-oil system and switch gear. Installation costs would approximately equal the equipment cost of $300,000 per unit.

Annual operating and maintenance costs (excluding fuel supply) are at 7% of installed equipment cost. A cost summary is shown below:

	ESTIMATED INSTALLED COST
3 Furnace-boilers (and associated equipment)	$ 3,000,000
Stack and bag filter	400,000
3 Steam turbine electricity generators	1,800,000
Miscellaneous (electrical gear, utility facilities)	900,000
Contingency (10%)	600,000
TOTAL INSTALLED COST	$ 6,700,000
Annual Operating Cost (excluding wood)	$ 469,000
Daily wood requirements of 480 tons at $15 per green ton delivered	$ 2,400,000/yr (90% steam factor)

Case Output: 3 MwH/hr electricity plus 105,000 lbs/hr of 150 psig, 470° F (superheated) steam

(2) Economic Analysis/Cost Effectiveness

Employing the escalation factors described in part 6.b.(2), the economic analysis summary for the direct combustion, cogeneration system is shown in Table 6. In brief, this option will result in:

- o A project capital cost of: $8,241,000
- o Annual energy savings of: 1,588,626 MBtu
- o An E/C ratio of (MBtu/$K): 193
- o A Discounted Benefit/Cost ratio of: 5.6
- o Annual dollar savings: $1,913,000
- o A payback period of: 4 years

	($K)	($K)
COSTS		
1. Non-recurring Initial Capital Costs		
a. CWE	$ 8,241	
b. Design	$ 426	
c. Total		$ 8,667
BENEFITS		
2. Recurring Benefit/Cost Differential Other than Energy		
a. Annual Labor Increase	$ 247/yr	
b. Annual Material Increase	$ 330/yr	
c. Other Annual Increase	-	
d. Total Costs	$ 577/yr	
e. 10% Discount Factor	8.933	
f. Discounted Recurring Cost (d x e)		$ 5,154
3. Recurring Energy Benefit/Costs		
a. Type of Fuel: ELECTRICITY		
(1) Annual Energy Decrease	304,348 MBtu	
(2) Cost per MBtu (Actual $)	$ 4.77/MBtu	
(3) Annual Dollar Decrease	$ 1,454/yr	
(4) Differential Escalation Rate (7%) Factor	15.363	
(5) Discounted Dollar Decrease	$ 22,340	
b. Type of Fuel: NATURAL GAS		
(1) Annual Energy Decrease	1,283,778 MBtu	
(2) Cost per MBtu (Actual $)	$ 3.66/MBtu	
(3) Annual Dollar Decrease	$ 4,699/yr	
(4) Differential Escalation Rate (8%) Factor	16.740	
(5) Discounted Dollar Decrease	$ 78,655	
c. Type of Fuel: WOOD		
(1) Annual Energy Increase	1,489,200 MBtu	
(2) Cost of MBtu (Actual $)	$ 2.46/MBtu	
(3) Annual Dollar Increase	$ 3,663/yr	
(4) Differential Escalation Rate (5%) Factor	13.018	
(5) Discounted Dollar Increase	$ 47,690	
d. Discounted Energy Benefits (3a(5) + 3b(5) - 3c(5))		$ 53,305
4. Total Benefits (3d - 2f)		$ 48,151
5. Discounted Benefit/Cost Ratio (Line 4 ÷ Line 1c)		5.6
6. Total Annual Energy Savings (3a(1) + 3b(1))		1,588,626 MBtu
7. E/C Ratio (Line 6 ÷ 1a/1000)		193
8. Annual $ Savings (3a(3) + 3b(3) - 3c(3) - 2d)		$ 1,913/yr
9. Payback Period (Line 1a - Salvage) ÷ Line 8		4 yrs

TABLE 6. Economic Analysis Summary
Demonstration Module: Option 2

d. Main Base System: Option 1 plus Option 2

(1) Capital (Installed Equipment) and Operating Cost

The Main Base System cost, being the sum of Options 1 and 2, detailed above, are summarized below:

Estimated Capital Cost	= $11.3 million
Annual Operating Cost	= $791,000 (excluding wood)
Annual Wood Supply Cost	= $3.24 million (90% steam factor)

Total Output: 7 MwH/hr electricity
105,000 lbs/hr 150 psig, 470° (superheated) steam
5,000 lbs/hr 150 psig saturated steam

Daily Wood Requirement = 650 green tons
($15 per ton, delivered)

(2) Economic Analyses/Cost Effectiveness

Employing the escalation factors described in part 6.b.(2), the economic analysis summary for the Main Base System is shown in Table 7. In brief, this option will result in:

- o A project capital cost of: $13,900,000
- o Annual energy savings of: 2,056,222 MBtu
- o An E/C ratio of (MBtu/$K): 148
- o A discounted Benefit/Cost ration of: 4.0
- o Annual dollar savings of: $2,381,000
- o A payback period of: 6 years

e. Entire Base Facility

(1) Capital (Installed Equipment) and Operating Cost

For the balance of Eglin's biomass-to-energy system, a central or a distributed combined cycle facility could provide the required energy. The particular advantage of a centralized facility is the elimination of duplication of equipment. A single centralized system is to be considered here.

		($K)	($K)
COSTS			
1.	Non-recurring Initial Capital Costs		
	a. CWE	$ 13,900	
	b. Design	$ 719	
	c. Total		$ 14,619
BENEFITS			
2.	Recurring Benefit/Cost Differential Other than Energy		
	a. Annual Labor Increase	$ 417/yr	
	b. Annual Material Increase	$ 556/yr	
	c. Other Annual Increase	-	
	d. Total Costs	$ 973/yr	
	e. 10% Discount Factor	8.933	
	f. Discounted Recurring Cost (d x e)		$ 8,692
3.	Recurring Energy Benefit/Costs		
	a. Type of Fuel: ELECTRICITY		
	(1) Annual Energy Decrease	711,312 MBtu	
	(2) Cost per MBtu (Actual $)	$ 4.77/MBtu	
	(3) Annual Dollar Decrease	$ 3,393/yr	
	(4) Differential Escalation Rate (7%) Factor	15.363	
	(5) Discounted Dollar Decrease	$ 52,126	
	b. Type of Fuel: NATURAL GAS		
	(1) Annual Energy Decrease	1,344,910 MBtu	
	(2) Cost per MBtu (Actual $)	$ 3.66/MBtu	
	(3) Annual Dollar Decrease	$ 4,922/yr	
	(4) Differential Escalation Rate (8%) Factor	16.740	
	(5) Discounted Dollar Decrease	$ 82,400	
	c. Type of Fuel: WOOD		
	(1) Annual Energy Increase	2,016,625 MBtu	
	(2) Cost of MBtu (Actual $)	$ 2.46/MBtu	
	(3) Annual Dollar Increase	$ 4,961/yr	
	(4) Differential Escalation Rate (5%) Factor	13.018	
	(5) Discounted Dollar Increase	$ 64,580	
	d. Discounted Energy Benefits (3a(5) + 3b(5) - 3c(5))		$ 69,946
4.	Total Benefits (3d - 2f)		$ 61,254
5.	Discounted Benefit/Cost Ratio (Line 4 ÷ Line 1c)		4.0
6.	Total Annual Energy Savings (3a(1) + 3b(1))		2,056,222 MBtu
7.	E/C Ratio (Line 6 ÷ 1a/1000)		148
8.	Annual $ Savings (3a(3) + 3b(3) - 3c(3) - 2d)		$ 2,381/yr
9.	Payback Period (Line 1a - Salvage) ÷ Line 8		6 yrs

TABLE 7. Economic Analysis Summary
Main Base

The gasifier configuration suggested for flexibility in operation--both turndown and sparing--would be six 50 MBtu/hr gasifiers (one spare), and five 5,000 Kw gas turbine generators (one spare). The gasifiers' cost was quoted at $525,000 each, installed, while the gas turbine generators were about $2 million each, also installed. Heat which could be recovered from the turbine exhaust gases should generate about 25,000 lbs/hr 150 psig saturated steam. This waste heat boiler system should not cost more than $1 million installed.

The figures below are for the incremental system to convert the biomass supply of energy from the Main Base system to an Entire Base facility.

	ESTIMATED INSTALLED COST
6 Gasifiers (each 20% capacity, including environmental control equipment)	\$ 3,200,000
5 Gas turbine-generators (including associated equipment)	\$10,000,000
Waste heat boiler (including flue gas stack and associated equipment)	\$ 1,000,000
Miscellaneous (electric gear, utility facilities)	\$ 5,000,000
Contingency (10%)	\$ 2,000,000
TOTAL INSTALLED COST	\$21,200,000
Annual Operating Cost (excluding wood)	\$ 1,480,000
Daily wood requirement of 830 tons at \$15 per green ton	\$ 4,100,000/yr (90% steam factor)

Case Output: 20 MwH/hr electricity and 25,000 lbs/hr
150 psig saturated steam

Thus, the overall data for the Entire Base facility are as follows:

Estimated Captial Cost = \$32.5 million
Annual Operating Cost = \$1.7 million
Annual Wood Supply Cost = \$7.3 million (90% steam factor)

Total Output: 27 MwH/hr electricity
105,000 lbs/hr 150 psig, 470° F (superheated) steam
30,000 lbs/hr 150 psig saturated steam

Daily Wood Requirement - 1480 green tons (\$15 per ton delivered)

(2) Economic Analysis/Cost Effectiveness

Employing the escalation factors described in part 6.b.(2), the economic analysis summary for thr Entire Base System (BEI) is shown

in Table 8. In brief, this option will result in:

- A project capital cost of: $40,000,000
- Annual energy savings of: 4,394,170 MBtu
- An E/C ratio of (MBtu/$K): 110
- A discounted Benefit/Cost ratio of: 3.1
- Annual dollar savings of: $5,032,000
- A payback period of: 8 years

	($K)	($K)
COSTS		
1. Non-recurring Initial Capital Costs		
a. C&E	$ 10,000	
b. Design	$ [illegible]	
c. Total		$ 12,962
BENEFITS		
2. Recurring Benefit/Cost Differential Other than Energy		
a. Annual Labor Increase	$ 1,200/yr	
b. Annual Material Increase	$ 1,600/yr	
c. Other Annual Increase	-	
d. Total Costs	$ 2,800/yr	
e. 10% Discount Factor	8.933	
f. Discounted Recurring Cost (d x e)		$ 25,012
3. Recurring Energy Benefit/Costs		
a. Type of Fuel: ELECTRICITY		
(1) Annual Energy Decrease	2,743,600 MBtu	
(2) Cost per MBtu (Actual $)	$ 4.[illegible]/MBtu	
(3) Annual Dollar Decrease	$ 12,087/yr	
(4) Differential Escalation Rate (7%) Factor	15.363	
(5) Discounted Dollar Decrease	$ 201,060	
b. Type of Fuel: NATURAL GAS		
(1) Annual Energy Decrease	1,650,570 MBtu	
(2) Cost per MBtu (Actual $)	$ 3.66/MBtu	
(3) Annual Dollar Decrease	$ 6,041/yr	
(4) Differential Escalation Rate (8%) Factor	16.740	
(5) Discounted Dollar Decrease	$ 101,130	
c. Type of Fuel: WOOD		
(1) Annual Energy Increase	4,591,700 MBtu	
(2) Cost of MBtu (Actual $)	$ 2.46/MBtu	
(3) Annual Dollar Increase	$ 11,296/yr	
(4) Differential Escalation Rate (5%) Factor	13.018	
(5) Discounted Dollar Increase	$ 147,050	
d. Discounted Energy Benefits (3a(5) + 3b(5) - 3c(5))		$ 155,140
4. Total Benefits (3d - 2f)		$ 130,128
5. Discounted Benefit/Cost Ratio (Line 4 ÷ Line 1c)		3.1
6. Total Annual Energy Savings (3a(1) + 3b(1))		4,394,170 MBtu
7. E/C Ratio (Line 6 ÷ 1a/1000)		110
8. Annual $ Savings (3a(3) + 3b(3) - 3c(3) - 2d)		$ 5,032/yr
9. Payback Period (Line 1a - Salvage) ÷ Line 8		8 yrs

TABLE 8. Economic Analysis Summary
Entire Base

f. Energy/Cost Comparison

Table 9 shows the energy/cost comparison for each system described.

	ELECTRICITY ($.036/KWH)		NATURAL GAS ($2.88/MCF)		WOOD ($15/TON)		NET SAVINGS		ECONOMIC EFFICIENCY	
	MMBTU/YR	$ M	MMBTU/YR	$ M	MMBTU/YR	$ M	MMBTU/YR	$ M	E/C	PAYBACK (YEAR)
MODULE 1	406,464	29.79	61,132	3.75	527,425	16.89	467,596	16.64	83	11
MODULE 2	304,848	22.34	1,283,778	78.66	1,489,200	47.69	1,588,626	53.31	193	4
MAIN BASE	711,312	52.13	1,344,910	82.40	2,016,625	64.58	2,056,222	69.95	148	6
BEI	2,743,600	201.06	1,650,570	101.13	4,591,700	147.05	4,394,170	155.14	110	8

TABLE 9. Energy/Cost Comparisons
(Escalated: 20 Year Life)

The electricity and natural gas figures are credits and the wood figures are debits to the net savings. The cost figures reflect the discounted present worth using the differential escalation rates taken from the ECIP guidance document and shown in Tables 5 through 8. It should be noted that, in the energy savings calculations, wood energy is considered "free", and only the costs are debited from the electricity and natural gas savings. This calculation affects the E/C ratio, but not the payback period.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

1. CONCLUSIONS

This study has shown that the forest resources on Eglin AFB, under proper management, are capable of supplying sufficient energy to support the base as a Biomass Energy Island. Further, the favorable economic efficiencies and technical suitabilities of the conversion systems described, and the cost avoidance that will be realized from the replacement of external source electricity and natural gas, support the conclusion that Eglin Air Force Base is an ideal candidate for the demonstration of the BEI concept.

By simply increasing the forest harvesting to approach the annual growth of the areas of Eglin AFB presently being harvested, the requirements of the Demonstration Module: Option 1 can be comfortably met. With forest harvesting and management expanded slightly from that level, the biomass feed requirements of the Option 2 facility can be met. However, if it were desired to install both options simultaneously, promptly initiated intensive forest management could have wood feedstock resources available to meet the desired start-up dates of both of the Demonstration Modules. Allowing a few years before proceeding to the final stages of biomass-energy applications (BEI) would permit the forest management staff of Eglin to plan and initiate an Energy Plantation forest management policy.

On the environmental side, little problem is anticipated for either the energy generation facilities, themselves, or for the biomass utilization plans. In fact, the intensified forest management, which would include removal of harvesting residues, slash, unhealthy trees, and growths, etc., would substantially upgrade the ecology of the Eglin AFB.

In recent discussions the need to maintain certain forested areas of the base exclusively for the testing of equipment was pointed out to Ultrasystems. Although this portion of the wooded area of Eglin was thought to be sizeable, the constraint of maintaining that area distinct from the area harvested should not be of too substantial influence on the resources required for the proposed biomass-to-energy systems. The detailed follow-on analysis would quantify this feature.

As was noted, Eglin's outlay for electricity plus natural gas was already approximately $10 million per year. Increases in both utilities are about to be imposed. Equivalent energies can be generated from the base's own biomass, thus removing Eglin from dependence on external source energies as well as moderating Eglin's off-base expenditures for energy.

According to the financial analyses completed, the rate of return for application of the commercially proven processes proposed is satisfactory, even without consideration being given to the value of Eglin AFB of having a confirmed energy source.

Due to these factors which became evident in this study, the need for follow-on study appears confirmed. An outline procedure for that detailed study is presented in the next section.

2. RECOMMENDATIONS

To begin employing the as yet untapped energy resources of Eglin AFB as rapidly as possible, a detailed follow-on analysis is essential. That study should include consideration of the following subjects: Optimization of types of energies generated based on existing/modified energy demand distribution; precise assessment of wood/residue resources available for use as energy source(s); design and scheduling of systems for installation.

a. Optimize Energy Generation Systems

Consideration needs to be given to the energies used and the energies to be generated from biomass in that some of the present energy uses may not be as efficient as they could be. Retrofitting energy consumers to convert from steam heating to electricity or from domestic use of natural gas to electricity, etc., may prove to be expedient, as may be appropriate. Further, precise determination of time variation in all energy demands will indicate seasonal, monthly, and time of day consumptions of energy. The level of demands to be met can be chosen, and a shedding program, if necessary, formulated.

Based on an energy audit and an economic analysis such as would be necessary, the energies required to be made available and the geographic locations of the users can be defined. The systems, both the technologies and whether they are to be centralized or distributed systems, can thus be determined. The breakdown of the processes and their sizes to convert biomass to energies for Eglin AFB can be optimized for the incremental and/or complete facility installation programs.

b. Formulate Biomass Harvesting Program

The biomass conversion systems selected to be employed and the unit designs will define the quantity of biomass required to be available. Variations in that quantity, if total energy demands do fluctuate sufficiently to warrant programmed energy production, will also be planned.

Based on these data, the acreage needing to be available, plus the level of harvesting and forestry management required can be defined. Planning for implementation of these features, together with environmental and ecological matters can be considered.

c. System Designs

Detailed design of the systems to be installed at Eglin AFB can commence as soon as the energy generation systems have been optimized. Equipment can be designed and specified, piping and units can be layed out, control and instruments can be sized and specified, and environmental control systems and permit applications can be planned. A schedule for each stage of biomass-to-energy system implementation can be formulated.

Each of the three preceding concepts refers to separate parts of the Eglin AFB energy systems, yet all are interrelated. A master-plan to embrace these three major groups of activities should be drawn up first, revealing the components and details to be incorporated in each of them. Although an overview, the master-plan should note every topic which has to be covered for a complete and successful project. Obviously, then, preparation of this master-plan for the detailed study should be the first step taken.

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APPENDIX A

Eglin AFB Boiler Data

APPENDIX A

EGLIN AIR FORCE BASE
BOILER DATA

NUMBER OF		NATIONAL BOARD NUMBER	MANUFACTURER	TYPE W.T. OR F.T.	OPR PRES-SURE	BHP	FUEL	YEAR	
BUILDING	BOILER							BUILT	INSTL
3	1	2851	Farrar & Trefts	F.T.	50	89.6	Gas Oil	1949	1949
3	2	2850	" "	"	50	89.6	"	"	"
17	1	16937	Kewannee	"	60	107	"	1952	1954
17	2	16935	"	"	"	107	"	"	"
18	1	17149	"	"	"	107	"	1953	1954
18	2	17150	"	"	"	107	"	"	"
19	1	17201	"	"	"	107	"	"	"
19	2	17148	"	"	"	107	"	"	"
20	1	16936	"	"	"	107	"	1952	1954
20	2	16939	"	"	"	107	"	"	"
21	1	3986	Superior	"	50	150	"	1969	1969
21	2	3360	Iron Fireman	"	50	80	Gas	1970	1970
130	1	6046	Titusville	"	"	107	Gas Oil	1952	1954
130	2	6045	"	"	"	107	"	"	"
440	1	26196	Kewannee	"	125	150	Gas	1974	1974
440	2	14183	B & W	W.T.	160	315	Gas Oil	1945	1945
440	3	14184	"	"	"	315	"	"	"

APPENDIX A

EGLIN AIR FORCE BASE
BOILER DATA

(Continued)

NUMBER OF		NATIONAL BOARD NUMBER	MANUFACTURER	TYPE W.T. OR F.T.	OPR PRES-SURE	BHP	FUEL	YEAR	
BUILDING	BOILER							BUILT	INSTL
573	1	22372	Cleaver-Brooks	F.T.	80	100	Oil	1970	1970
573	2	22369	" "	"	"	100	"	"	"
874	1	9897	" "	"	135	200	Gas Oil	1960	1961
874	2	9748	" "	"	135	200	"	"	"
2825	1	10934	International	W.T.	70	250	"	1966	1967
2825	2	10933	"	"	"	250	"	"	"
3053	1	16764	Kawannee	F.T.	60	125	"	1952	1954
3053	2	16765	"	"	"	125	"	"	"
6002	1	19570	Cleaver-Brooks	"	"	30	"	1965	1965
12530	1	314	Holmar	W.T.	275	33/8	Oil	1957	1958
12530	2	313	"	"	"	33/8	"	"	"

APPENDIX B

Gasification and Combined Cycle Literature

SIMONS-EASTERN CO.
ATLANTA, GEORGIA

Gasification designs get cooler, economical

Three wood gasification installations which together could furnish equivalent electricity for a city of 100,000 are now being planned and designed by engineers in the wood products group of Simons-Eastern Co., Atlanta, GA USA.

Two of the three installations, 10 megawatts each, are, in fact, municipal generating plants which, through retrofit, will power boilers with wood gas instead of natural gas. The third is a 15 megawatt co-generation unit which will provide electricity through use of an internal combustion engine. Two of the units are scheduled to be operating during 1981.

The sawdust and refuse to be used as fuel by the municipal plants is currently land fill material and will be transported to the site by truck.

The efficiencies of the gasification system, such as that being designed for Bio-Fuels, Inc. of Louisiana, come from two sources according to these Simons-Eastern engineers. The first is the ability to produce gas from wood waste at less than 200°F so that it can be economically cleaned and burned in an internal combustion engine. The second is simply to use it that way — in an internal combustion engine.

The new look in wood waste, gas being produced at 175°F exit temperature from a Halcyon Gasifier ready to fuel a boiler or dryer or, an even more efficient use, to power an internal combustion engine for generating electricity.

The efficiency of generating electricity from wood waste or coal by first burning it to make steam is 30 to 35 percent. However, converting the wood to gas and then using it to power an internal combustion engine is 55 to 60 percent efficient.

Another advantage is that, unlike the direct burning of wood waste or coal, emissions from gasification and wood gas use are non-polluting. ■

Simons Engineering World 2 • 1980

HALCYON ASSOCIATES, INC.
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HALCYON GASIFICATION SYSTEMS

With the producer gas systems used prior to and during World War II in Europe and in North America, coal was the usual fuel with biomass being used as a fuel only in the so-called "deprived countries".

However, extensive fuel preparation is necessary with most types of producer gasification systems. The coal units are limited to certain non-coking coals and even then, the coal has to be uniform in size, preferably golf ball size or larger.

With wood, the Europeans today specify that the wood must be less than 20% moisture and that it should in size be not less than matchbox size and not larger than a brick. Ingenious devils, they have designed two-way gang saws, which cut lumber boards into the right sizes. These gasifiers are mainly downdraft or cross draft types, have high exit temperatures, and are pressurized vessels.

Our gasifier, by purpose and intent, is designed to use green or dry chips, bark, hogged fuel (the normal waste fuel from the forest products industry) without any pre-preparation of the fuel other than removal of oversize lumps, rocks, etc. by screening. Actually, the gasifier usually is not what decides the larger limits in size. This is normally determined by the material handling system.

The only material that cannot be gasified successfully is 100% of dry fine sander dust or sawdust, although a proportion of this material in the feed is acceptable.

Preferably, the material should not be of uniform size, but a mixture of many sizes, just as it comes from a hog or chipper.

Although we have successfully gasified waste chipboard and particle board (3" x 3" x 2" in size and containing 9% urea formaldehyde bond) and some varieties of pellets and briquettes, the best results have been obtained with hogged waste and bark, and chips, where no densifying has occurred and where the natural porosity of the wood enhances drying and the distillation of volatiles.

Economics play a large part in the fuel requirements as it obviously is much cheaper to use fuel not requiring any pre-preparation than it is to obtain dry, uniform size, pelletized, or briquetted fuels.

A further consideration in our gasifier, cognizant of the dangers of carbon monoxide, is that the gasifier is under negative pressure, so that if a leak occurs, air will be drawn in rather than gas leak out. In gasifiers where air is blown in under pressure, the vessel is pressurized and thus gas escapes through any opening such as the feed, observation ports, etc. With our suction gasifier, a port or door can be opened while the unit is in operation without any egress of gas. This is a valuable safety feature.

The stated advantage of the down draft gasifier over the up draft gasifier is that the tars are cracked and partially destroyed in the reduction zone, located below the combustion zone. However, when the temperature of the gas is kept low enough, the tars do not crack into pitch and are readily collected and used. In our gasifier, part of the tars and wood oils are collected on the wood in the drying zone and the heavier tars are contained in the vessel, as the gas exit temperature normally is around 250°F.

The scrubber/condenser/separator system on our gasifier removes the remainder of the tars and wood oils, and surplus water from the wood. The surplus water is evaporated in a small cooling tower, and the wood tars and oils are burned as a fuel or utilized otherwise.

This oil has a heating value of 100,000 BTU per gallon and can be burned in conjunction with burning the gas.

In the scrubber system, the gas is cooled to 120°F, water vapor in the gas is condensed, the condensables (tars, oils, etc.) are condensed, the gas is cleaned to remove 96% of all contaminants over 5 microns and 98% over 10 microns.

When burned in a Halcyon burner, the products of combustion will have particulates, without any cleaning whatever of these combustion or flue gases, of less than .025 pounds per million BTU, extremely low Nox, and zero opacity.

As the gas temperature is $120^{o}F$ or below, there is no derating in capacity of the burner due to high gas temperatures, and no high temperature materials are required. Standard control equipment may be used with cool clean gas and the burners have the same type of safety controls (flame failure, etc.) similar to that on oil or natural gas burners, to meet insurance company requirements and applicable codes and ordinances.

By removing the water in the gas, the flame temperature at the burner should be high enough to maintain boiler capacity and efficiency. When the water is not removed, the flame temperature is relatively low.

Cool clean gas can be piped for long distances if necessary, and this precludes the necessity of having to close-couple a gasifier or combustor to the boiler, furnace, dryer, engine, turbine, etc.

It also allows multiple use of the gas, for example firing a boiler, direct power generation, direct engine drive, direct firing kilns or furnaces, simultaneously.

The aim of all energy producing systems is to provide maximum energy output with minimum energy input. Fluidized bed equipment requires high energy input in relation to output, and this also applies to high energy input required for fuel preparation. One horsepower input per million BTU produced only is required for our system, excluding wood or fuel handling.

Summarizing all of the above:
What we have tried to achieve is a practical and efficient gasifier which will take fuel normally available without expensive and energy consuming drying or other pre-preparation; will produce cool clean gas which can be utilized efficiently in different applications, meeting all emission standards; which can be centralized or remotely located; which is safe relatively compared to pressurized vessels; and which takes very little energy input in relation to output.

The initial capital cost is very much lower, especially as the gas can fuel existing equipment without costly retro-fitting.

The gas, after cleaning and cooling, has a heating value of between 140-170 BTU per cubic foot.

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HALCYON GASIFICATION SYSTEMS

The gasifier is an upright cylindrical vessel with the feed at the top, ash removal at the bottom, air and steam entering at the bottom, and gas leaving at the top.

In height, the gasifier is designed to provide sufficient bed depth for the combustion, reduction, distillation, and drying zones.

The diameter of the vessel is determined by the capacity required. As with any boiler, the rate of combustion on the grate area determines the amount of fuel consumed commensurate with the production of relatively clean gas without ash fusion and excessively high gas temperatures.

The Halcyon gasifier is designed to operate below ash fusion temperatures and produce gas with little sensible heat and very little latent heat in the gas itself.

At the bottom of the vessel, there are fully cleanable, water cooled grates to hold the fuel. Air and steam enter below the grate. These are only sufficient to provide partial combustion of the fuel, and the steam is used to control grate temperature in addition to hydrogenation.

The chemical reaction in the gasifier is:

Drying Zone

$$\text{Wet Wood} + \text{Heat} \longrightarrow \text{Dry Wood} + \text{Water Vapor}$$

Pyrolysis Zone

$$\text{Dry Wood} + \text{Heat} \longrightarrow \text{Charcoal} + CO + CO_2 + H_2O + CH_4 + C_2H_4 + \text{Pyroligneous Acids} + \text{Tars}$$

Reduction Zone

$$C + CO_2 \longrightarrow 2CO$$

Oxidation Zone

$$\text{Charcoal} + O_2 + H_2O \longrightarrow CO + H_2 + CO_2 + \text{Heat}$$

Chemical Reaction

$$C + O_2 \longrightarrow CO_2$$

$$C + CO_2 \longrightarrow 2CO$$

$$H_2O + CO \longrightarrow CO_2 + H_2$$

$$H_2O + C \longrightarrow CO + H_2$$

Some reactions are exothermic and some endothermic.

The gases leaving the Halcyon gasifier are cooled and cleaned in a scrubber/condenser/separator system. Tars and surplus waters are removed.

The gas passes through secondary cleaning to remove any moisture carried over, then goes to the gas fan. At this time, the gas is near to or just above room temperature.

From the fan, the gas goes to a Halcyon low calorific gas burner, where it can be burned direct or in a pressurized boiler. The burner can be a combination of producer gas, natural gas, and oil firing.

A series of controls on the gasifier allows for automatic operation with little supervision.

Feed to the gasifier is controlled by external upper and lower level controls which start and stop the air lock and feed equipment.

Cooling water is thermostatically controlled.

Grate temperature is controlled by automatic steam and/or water regulation.

Output is controlled by regulating the gas flow actuated by boiler steam pressure or dryer or furnace temperature. Flame failure safety features are included.

On power generation, the gas is cleaned further to remove all particulates above 0.1 micron and is piped directly to a modified gas or diesel engine (or gas turbine).

Advantages:

Low power input.

No ash or silica fusion.

Meets E.P.A. emission standards without any emission cleaning.

Minimal fuel preparation - No drying, densifying, or uniform sizing.

Can be used on existing oil or gas fired equipment.

May be located some distance from equipment using the gas - Does not require to be close-coupled.

Low first cost.

Low operating costs.

Adaptable for multiple uses.

Uses:

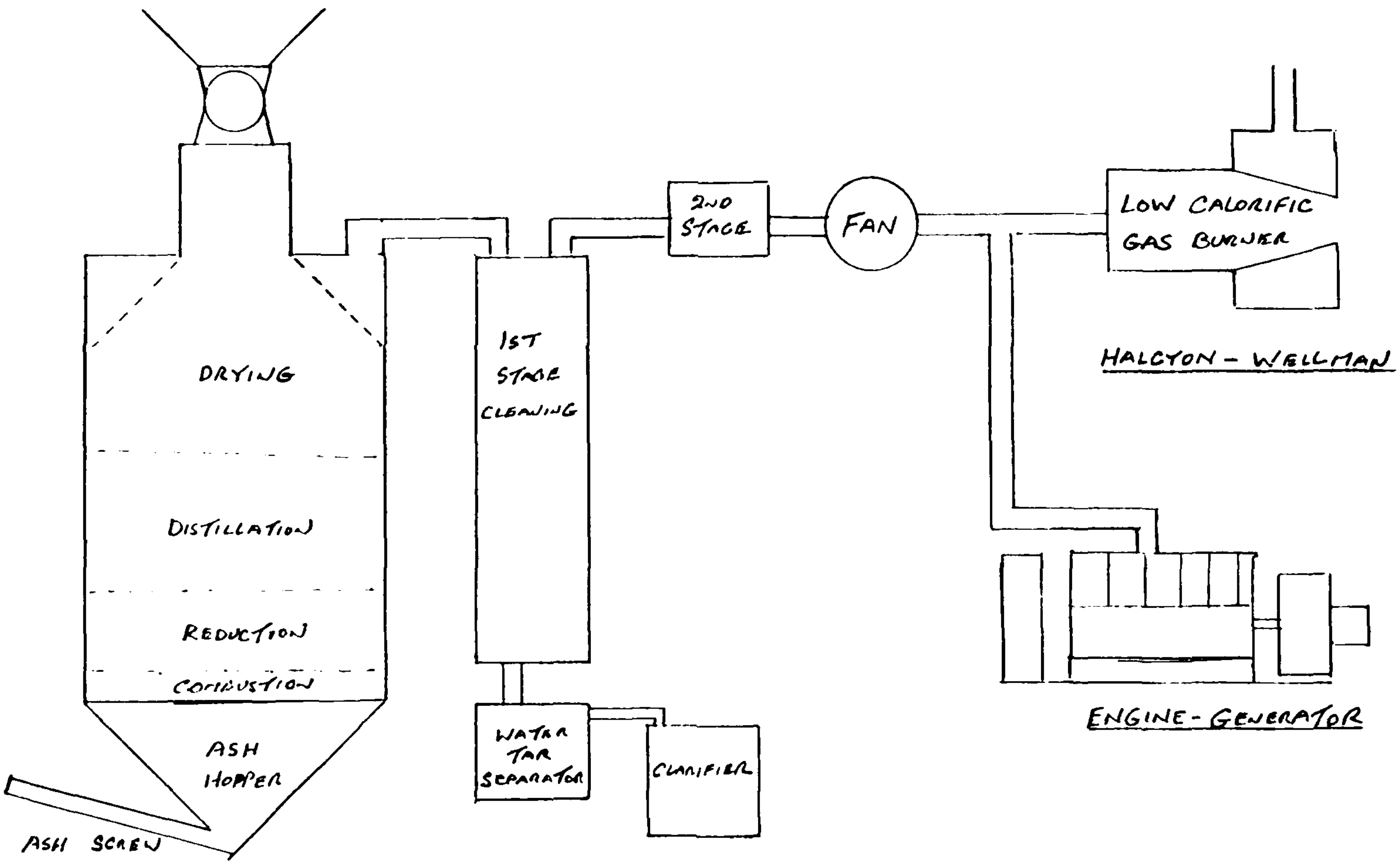
Direct firing of kilns, dryers, furnaces, etc.

Generation of steam in boilers.

Overfire of large hog fuel fired boilers and incinerators.

Efficient power generation in engines or gas turbines.

HALCYON ASSOCIATES INC. EAST ANDOVER, N.H



HALCYON GASIFIER SYSTEM

GEORGE FINNIE P.E.

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POWER GENERATION

Having produced cool clean gas, it is now possible to apply this gas to direct power generation.

One way to produce power is to generate steam in boilers at high pressures and temperatures, and utilize this steam in steam turbines or steam engines. This is the way it is done by the utilities, using either fossil fuels or nuclear generation of steam. Even with the economy of size, extremely high pressures and temperatures, the thermal efficiencies of utility size facilities does not exceed 35%. Most of the latent heat is dissipated in the condenser cooling water.

Paper mills and other users of large quantities of low pressure steam for drying, and applications of co-generation, can achieve higher overall efficiencies. Generally, however, where extraction or back pressure steam cannot be utilized and where the steam has to be condensed in condensers, thermal efficiency is low.

At the steam pressures and temperatures normally acceptable in smaller plants, not only is thermal efficiency low, but the high water rates (quantity of steam) required per KWH necessitates the installation and operation of greater capacity equipment than would normally be required.

A typical example, let's take a plant which has a demand for 1000 KW and a 15 PSI steam use for kiln drying of 10,000 pounds per hour. (This would dry around 500,000 board feet of lumber.)

Without power generation by steam, a 300 HP low pressure boiler would suffice to meet the kiln or drying need.

However, to generate 1000 KW at say 250 PSI, the steam required for drying would only produce 200 to 250 KW and a further 20,000 pounds would be required to produce the remainder, the steam going through a condenser. The total rate of 30,000 pounds per hour would require a boiler at least 3 times the capacity and 17 times the pressure of that required for steam only. In some states, this requires licensed engineers and firemen. Directly burning green wood, some 6 tons is required to provide this amount of power and steam.

Let us look at a different method of generating power and steam.

For over 100 years, the principal use of producer gas was to fuel engines. Most of these were the horizontal type and most were direct drives for line shafts, etc. During World War II, many vehicles had gasifiers to provide fuel for motive power. Today, trucks in Sweden are powered by producer gas.

To generate a KW of power requires around 13,000-14,000 BTU of producer gas. The Europeans with special engines claim 9,000, but let's stick to straight conventional engines, readily available here.

Allowing for the efficiency of the gasification system, 4 pounds of green (50% moisture) wood will provide 14,450 BTU of gas, which is ample to produce one KWH.

Taking the same example as we did previously for steam, 1000 KW of power will require 4,000 pounds or 2 tons of wood. To produce 10,000 pounds of steam requires 1.85 tons of green wood, so that a total of 3.85 tons will provide the same power and steam as it takes 6 tons in a boiler system.

However, this can be reduced further by utilizing the waste heat from the engine and gasifier. An ebullient or waste heat boiler will recover sufficient heat to produce 5,000 pounds of steam. Only 5,000 pounds will be required to be produced by directly burning gas in a boiler. Fuel requirements can be reduced to less than 3 tons.

In capital cost, it is doubtful whether a high pressure boiler-steam turbine system of the sizes stated can be installed for less than one million dollars, excluding wood handling.

A gasifier-engine generator-low pressure steam system should be installed for less than half that, and if used or existing engine-generator sets and existing boilers are adapted, then the installation will cost even less.

How easy or how difficult is it to produce power from gas derived from wood waste or agricultural waste - biomass materials?

Like gasification, only half of what is written about it is fact. The other half is erroneous, tends to confuse the issue, and hinders progress.

Much has been written vis-a-vis 2-stroke vs. 4-stroke, turbo-charged after-cooled against natural aspirated, compression ignition (diesel) vs. internal combustion (spark ignition), etc. The French insist that diesel is the only way to go, while the Swedes and Germans insist that the only way is spark ignition.

At the end of World War II when experience and knowledge of producer gas prime motivation was at its peak, almost any engine could be made to operate on producer gas. True, some operated better than others, but it mainly was the quality, cleanliness, and temperature of the gas which determined the quality of operation, more than the engine used.

With diesel operation, 4-10% diesel fuel is required for ignition, exactly as it is on dual fuel engines.

Turbo-charged after-cooled engines provide better volumetric efficiency of the engine, as do natural aspirated. This applies also to natural gas fired engines.

As there is a derating in capacity between a diesel fueled engine and the same engine on natural gas, there may be an additional derating between natural gas and producer gas operation on the same engine. This varies with the size, type, speed and compression ratio of the engine.

Generally, the larger the engine, the slower the speed, the higher the compression ratio, the less derating. Tests on engines to date indicate that output between natural gas and producer gas fuels, on the same engine, may result in a derating in output with producer gas of between 0% and 20%.

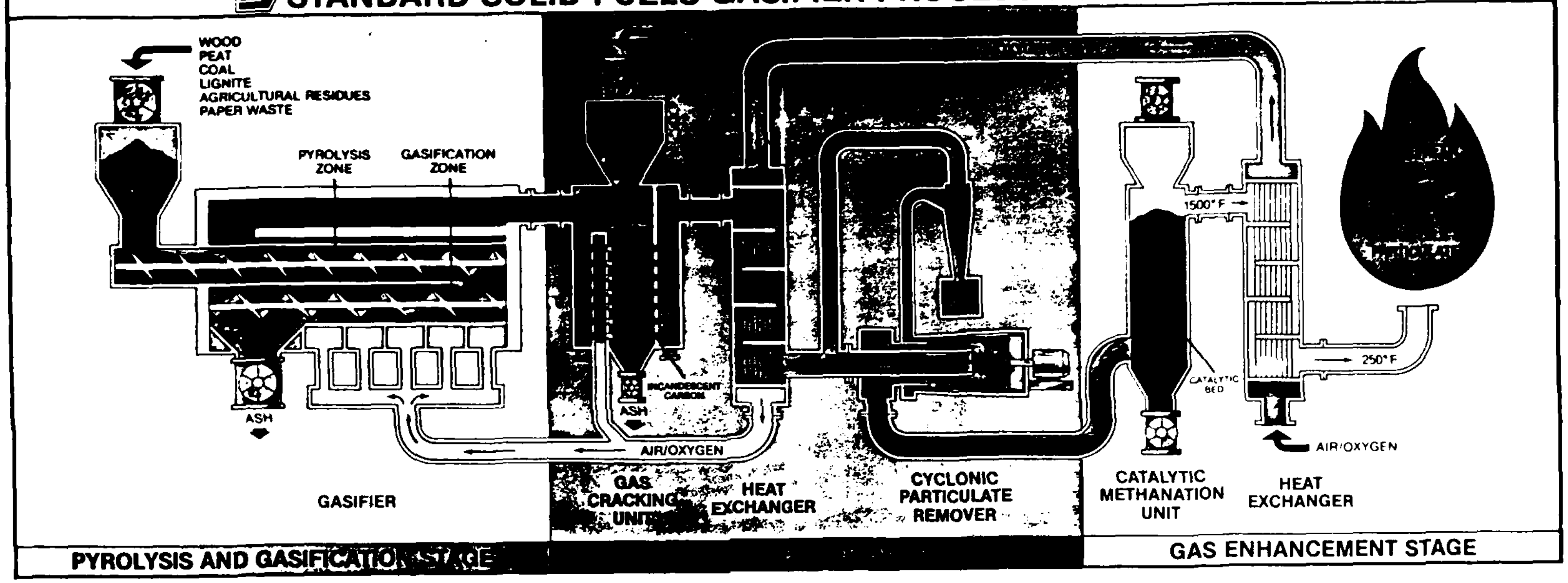
On most engines, the carburetor has to be changed to allow for the larger gas volume and the different air to gas ratio. The timing has to be retarded to allow for the burning velocity of the hydrogen.

At one time, automobiles, including the one I first owned, had lever operated advance and retard selection and gasoline mixture selection located on the steering column.

Today, of course, with man having less knowledge and progressive laziness, either it is done automatically or not at all. To permit operation of engines with different fuels, say natural gas and producer gas, some method is necessary to change ignition timing and air to gas ratios when changing from one fuel to another.

STANDARD SOLID FUELS
EVERETT, WASHINGTON

STANDARD SOLID FUELS GASIFIER PROCESS FLOW SCHEMATIC



GASIFICATION — A NEW SOLUTION TO ENERGY PROBLEMS

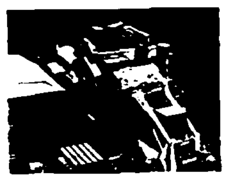
A NEW FUEL FLEXIBILITY

SUBSTANTIAL COST SAVINGS

Many readily available solid fuels are onehalf to one quarter the cost of natural gas and oil. In many areas suitable waste materials are available and offer greater cost savings.

EASY PLACEMENT IN EXISTING PLANTS

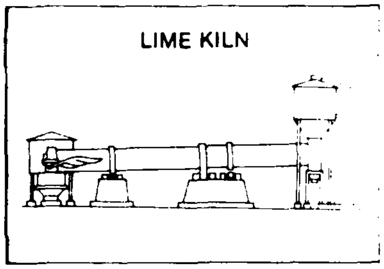
with incandescent carbon particulate removal and catalytic reforming. The compact skid mounted equipment may be quickly installed and placed in a location convenient to solid fuel storage facilities or process equipment.



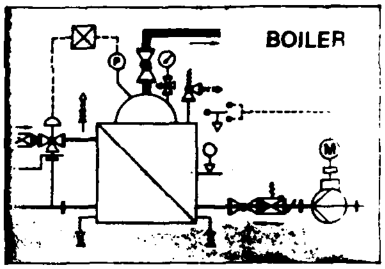
RELIABLE EQUIPMENT

STANDARD SOLID FUELS

APPLICATIONS



- Lime Kilns
- Lumber Kilns
- Brick Kilns
- Packaged Boilers
- Flash Dryers
- Rotary Dryers
- Yankee Dryers
- Process Equipment



POTENTIAL FUELS

- Wood
  - Bark
  - Hogged Fuel
  - Sawdust
  - Sander Dust
- Peat
- Coal
- Lignite
- Paper Waste
- Agricultural Residues
- Municipal Wastes (RDF)

INDUSTRIES

- Pulp & Paper Mills
- Sawmills
- Plywood, Particleboard Plants
- Refractory Plants
- Textile Mills
- Industrial, Commercial & Institutional Heating & Cooling

SIZES

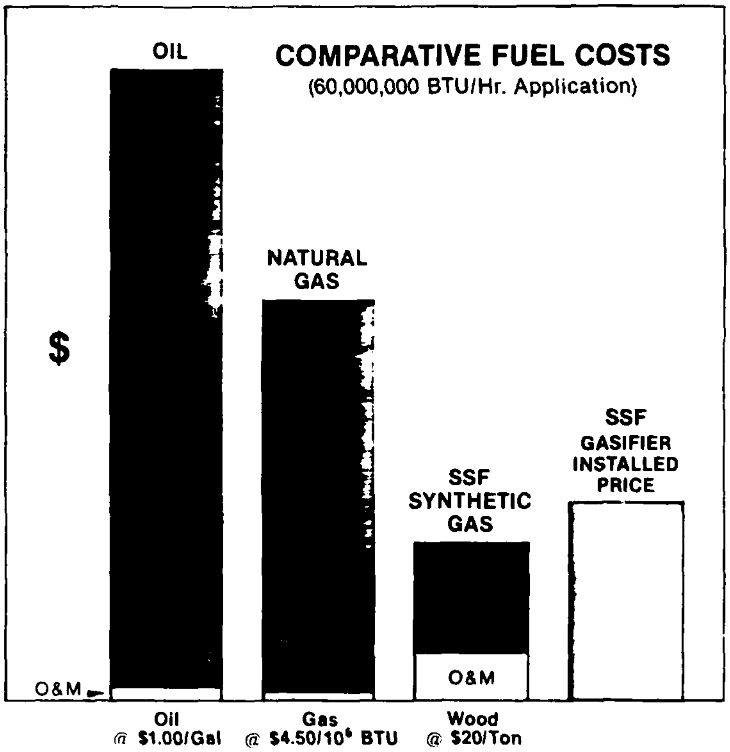
- Standard Single Line Modules from 20,000,000 BTU/Hr. to 100,000,000 BTU/Hr.

FINANCING OPTIONS

- Direct Purchase
- Equipment Lease
- Gas Purchase

AVAILABILITY

- 4-8 Months from Equipment Order to Startup



STANDARD SOLID FUELS PRODUCTS AND SERVICES:

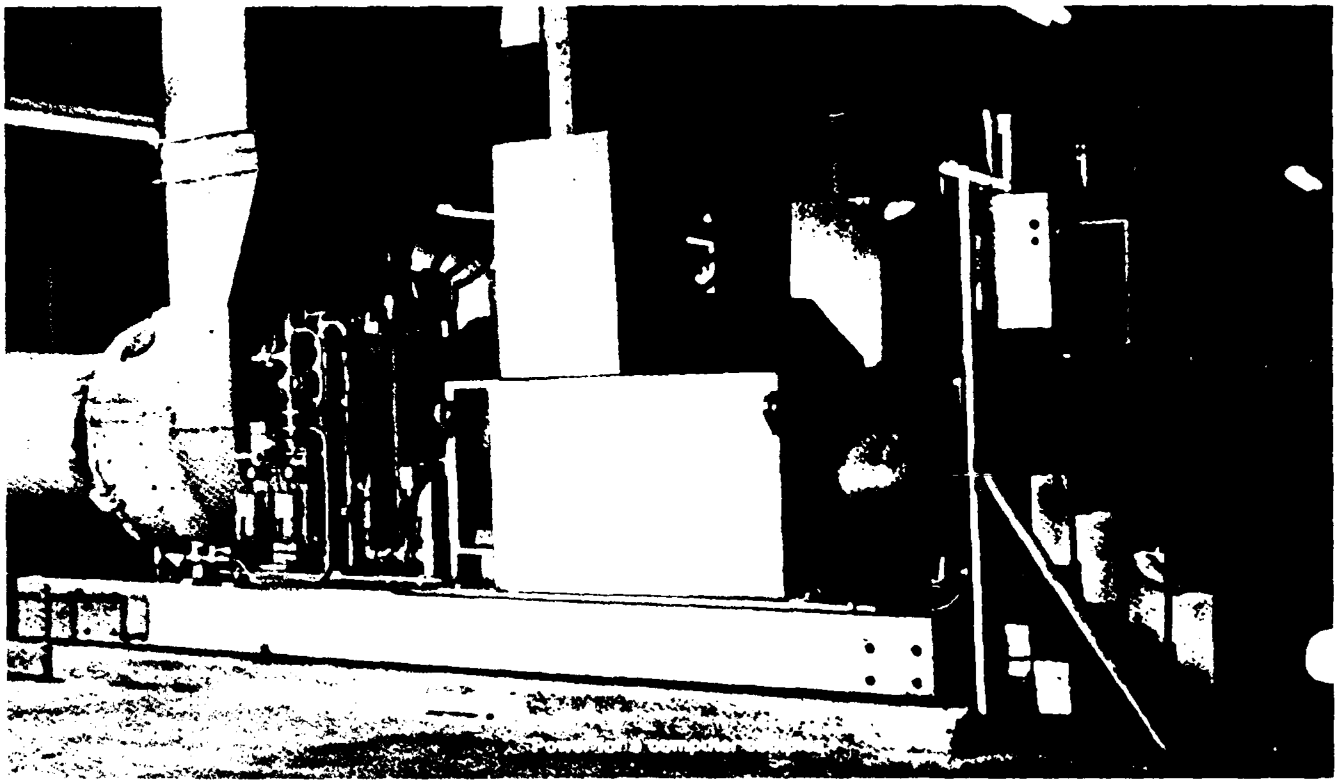
- Gasification Systems
- Combustion Systems
- Char Production Systems
- Material Handling Systems
- Dust Control Systems
- Dryer Systems
- Engineering
- Consulting
- Testing

STANDARD SOLID FUELS

3307 Cedar St.
P.O. Box 1389
Everett, WA 98206
Phone (206) 252-5761 • (206) 259-0168

NORTH AMERICAN TURBINE CORPORATION
HOUSTON, TEXAS

NATCO...GAS TURBINE POWER



- Gas Turbine Generator Sets for Continuous Duty or Standby-Emergency Power Generation
- Total Energy Cogeneration Systems
- Mechanical Drive Units for Pump and Compressor Drives

NATCO

NORTH AMERICAN TURBINE CORPORATION

HOUSTON, TEXAS U.S.A. / DIVISION OF KONGSBERG NORTH AMERICA

NATCO...
Gas Turbine Power

THE SOURCE

North American Turbine Corporation is a proven source for gas turbine powered generator sets and mechanical drive units, their supporting systems and parts and service worldwide.

NATCO was founded in 1969 to design, manufacture and support gas turbine powered systems and to specialize in the advancement of applied turbine technology for industrial applications. Backed up by the experience and technical expertise of their 166 year old parent company, Kongsberg, NATCO has become a major, world-wide supplier of turbomachinery and is recognized for outstanding service support and high quality products.

Over the years, NATCO has continued to develop and expand their product line. Now, a decade since its founding when it offered a single 1200 KW generator set package, NATCO offers generator sets from 300 to 5000 KW and mechanical drive units from 500 to 7000 horsepower.

We strive to be flexible to serve our customers in the best possible manner and to support our product once it is operational.

NATCO is unique in its ability to provide a wide range of proven turbine powerplants so that it may respond to specific customer power requirements and operational conditions. Powerplants that can burn a wide range of fuels, that are adaptable to worldwide environmental conditions and that can be easily operated and maintained.

A highly qualified and experienced engineering staff translates customer specifications to working drawings. With a background in turbomachinery, industrial packaging, power and electronics, our staff is capable of modifying the basic standard production hardware to meet the specific requirements of such diverse jobs as an offshore petroleum production platform, a hospital in a mideastern desert or a computer center in mid-town Manhattan.

This flexibility extends itself to the manufacturing group where they translate the products of Engineering to working hardware. With knowledge gained from experience in the working environment of the end product, they understand the need for first class workmanship, for adequate protective coatings and for only the best in Quality Control.

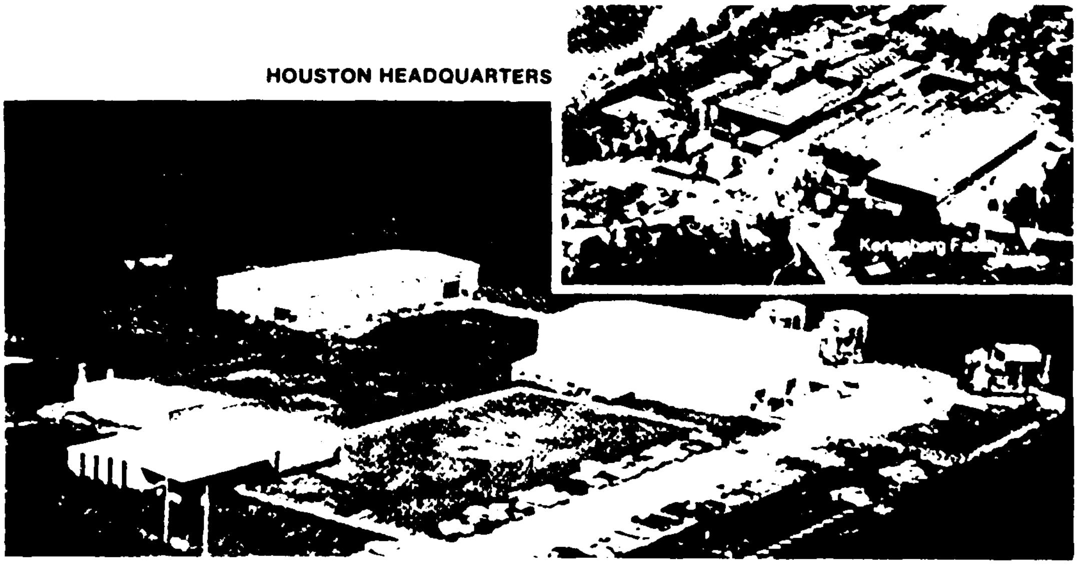
Every NATCO product is completely tested with its own starting and control system, with fuel or fuels similar to those to be used at the jobsite and—if requested—to a test specification reflecting the customers specific requirements.

The follow-up to a successful product is service. NATCO provides this to all its customers on a worldwide basis in cooperation with Kongsberg. Service and Parts Centers are strategically located in the U.S., Eastern Europe, the Mideast and Southeast Asia. Additional centers will be activated as the equipment population demands.

Management is the key to success. NATCO management believes in producing a superior product, in responding to the desires of the marketplace and in supporting the product wherever it may be in operation.

NATCO is unique as a packager of gas turbine driven generator sets and mechanical drive systems. Through Kongsberg we are closely associated with a manufacturer of turbine prime movers and have available the expertise and understanding that insures maximum performance and reliability of our products.

HOUSTON HEADQUARTERS



NORTH AMERICAN TURBINE CORPORATION

NATCO GAS TURBINE POWER

Industrial Gas Turbine Generator Sets
from 300 to 5000 KW
for Continuous Duty and Standby/Emergency Applications

THE NEED Offshore, on board ships, in the middle of a desert, in a remote arctic village, in a hospital, a computer center, or a telephone exchange—anywhere dependable power is required for base load or standby/emergency applications—NATCO has a gas turbine generator set to meet the requirements. Where consistent and reliable electrical energy is important; where space is at a premium; where low emission and noise levels are limiting; where frequency response is important, that's where we fit in—with more power per square foot, more power per pound weight. The NATCO family of gas turbine generator sets can provide this power—and more. We can provide complete system responsibility for your total energy requirements.

THE GAS TURBINES The NATCO KG series of gas turbines are proven in marine and industrial service throughout the world. Each have their own unique advantages for specific applications, for various available fuels and for available levels of maintenance. The feedback from NATCO's application experience to our own turbine engineers provide constant product improvement and development. Thus, we provide the knowledgeable link between user and manufacturer.

DEPENDABILITY—DURABILITY The NATCO KG-831, KG-2, KG-5, KG-501 and KG-570 gas turbine generator sets have been designed for continuous duty industrial applications. Proven system components are selected based on their ability to withstand constant demanding use. The materials for piping, tubing, seals and fastenings are of the best quality for the intended application. This, combined with the care and skill of dedicated assembly personnel and an experienced quality control staff, assures the highest quality end product—a gas turbine generator set designed, manufactured and tested to meet the most challenging applications. The care taken in manufacturing plus the ease of maintenance found in a NATCO turbine generator set gives you a combination that provides dependable power—*continuously or for standby/emergency applications*—for your specific requirement.

The gas turbines are unmatched in reliable steady power. Operating on diesel or gaseous fuels, NATCO turbines have extremely low emission, provide higher start reliability and voltage frequency stability. Available from 300-5090 KW (375 to 6362 KVA) one of the NATCO turbine generator systems is best for your application. We offer a broad range of power in a choice of five different component sets to match your specific needs.

NATCO KG-831	300-570 KW	(375-712 KVA)
NATCO KG-2	1200-1800 KW	(1500-2250 KVA)
NATCO KG-5	2100-3130 KW	(2625-3912 KVA)
NATCO KG-501	2750-3850 KW	(3437-4812 KVA)
NATCO KG-570	4000-5090 KW	(5000-6362 KVA)

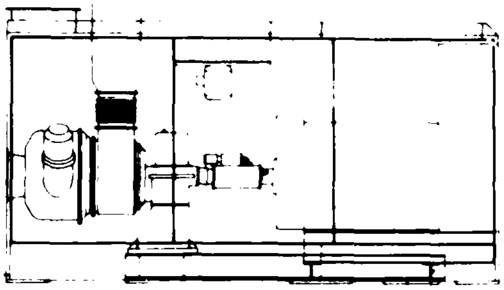
STANDARD OR CUSTOM DESIGN North American Turbine understands the need to be flexible in the design of gas turbine generator sets to meet the needs of the customer's specific job specification. We are also aware of the economics of a standard product. Our engineering and manufacturing organization are geared to respond to requirements for special metering, fuel handling, coatings, material, API specifications, etc., through the use of a wide choice of controlled options that permit the customizing of a standard unit to meet specific requirements.

This flexibility extends to product testing as well—we're willing to test to our standard specifications or your special requirements—whichever fits your needs.

SERVICE AND SUPPORT Through our association with the Gas Turbine and Power Systems Division of Kongsberg, we offer worldwide service and parts support. We can supervise installation, or take on total turnkey responsibility. We offer service and maintenance contracts as well as total operational responsibility if you so desire.

Parts depots are strategically located to support current installations. The lightweight gas turbine and modular system design lend themselves to easy transport and air freight in addition to minimizing downtime for repairs and maintenance.

THE ANSWER When you consider total installed cost per KW, maximum reliability, flexibility of product engineering and after-sales support—look to NATCO for your power generation requirements.



10'4" L x 4'3" W x 5'6" H
313 cm x 130 cm x 167 cm
Weight: 6500 lbs / 2950 kg

300 to 570 KW (375-712 KVA)

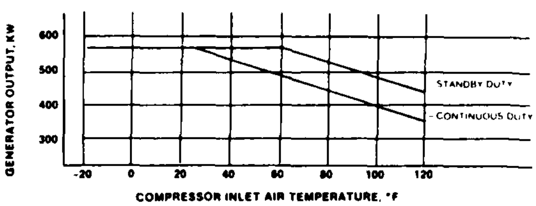
NATCO KG-831

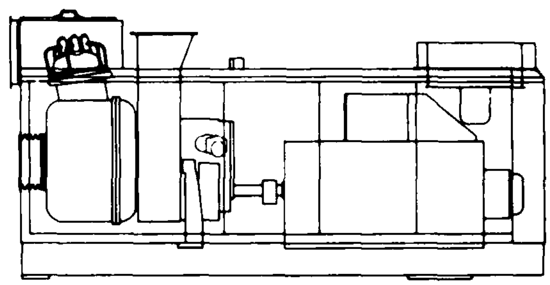
The NATCO KG-831 gas turbine generator set provides a compact, easily installed and completely self-contained power module comparable to diesel sets with the additional advantages of the turbine: low vibration, low emissions, ease of installation, low maintenance and superior quality of electrical output.

The KG-831 turbine powerplant has been in production for over 10 years, with several installations having in excess of 60,000 hours operation.

The turbine, generator and all support systems and controls are mounted on the structural skid. If desired, a 480 V. circuit breaker can be set mounted, and the entire unit covered with a sound attenuating enclosure.

TURBINE: KG-831 single shaft, industrial gas turbine rated 800 HP with two-stage centrifugal compressor, three-stage axial turbine, single tangential combustor, integral 1800 RPM double reduction gear, flexible drive coupling, and integral accessory drive gear.
GENERATOR: Rated 300-570 KW (375-712 KVA), 480V, 0.8 power factor, 60 Hz brushless-type exciter, static voltage regulator.





16'6" L x 5'6" W x 6'8" H
501 cm x 168 cm x 202 cm
Weight: 22,800 lbs / 10,342 kg

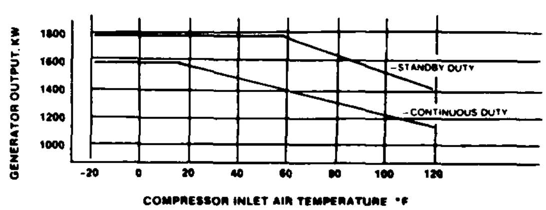
1200 to 1800 KW (1500-2250 KVA)

NATCO KG-2

The NATCO KG-2 gas turbine generator set is powered by the proven KG-2 all-radial industrial gas turbine. The 1800 KW generator set provides the most power per square foot of installed space in its size range.

The generator set is mounted on a rigid steel base which contains or mounts the complete fuel, lubrication and starting systems. Either a skid-mounted or free-standing turbine control panel houses the NATCO Turbotronic control system and, if desired, generator controls and low voltage breakers.

TURBINE: KG-2 single shaft, radial, industrial gas turbine rated 2500 HP with single-stage radial compressor and single-stage radial turbine, single tangential combustor, tilting pad radial and thrust bearings, flexible coupling and integral reduction/accessory gear drive.
GENERATOR: Rated 1200 to 1800 KW (1500-2250 KVA), 480V, 0.8 power factor, 60 Hz, brushless type exciter, static voltage regulator.



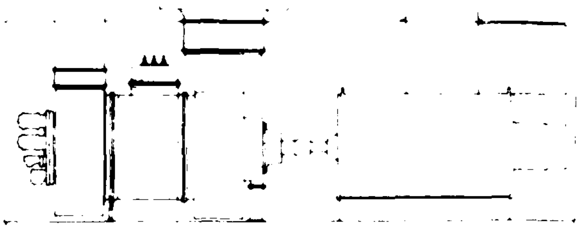
STANDARD SYSTEMS

- **GOVERNOR:** Woodward 2301 electronic load sensing. For multi-unit operation, isochronous (constant speed) control. Speed droop 0-5%. Woodward PSG. Speed droop 0-5% (KG-831 only)
- **TURBINE CONTROLS:** (Set mounted on the KG-831) Free standing system with 24 volt NATCO TURBOTRONIC control system with relay logic.
- **FUEL SYSTEM:** Liquid, No. 2 diesel or equal
- **STARTING SYSTEM:** D.C. electric starter (KG-831 and KG-2)
  Air/Gas starter (KG-5, KG-501 and KG-570)
- **LUBRICATION SYSTEM:** Complete, self-contained on skid. Includes reservoir, pump, filters, low pressure and high temperature controls, air-to-oil cooler(s) and pre-post lube system if required.

PERFORMANCE...All ratings are at ISO conditions of 59°F (15°C) sea level and with no inlet or exhaust losses.

Model Number	ISO RATING Continuous KW	Standby KW	COMPRESSOR Stages	Ratio	TURBINE Stages	RPM	POWER TURBINE Stages	RPM
KG-831	490	570	2	11.1:1	3	41730	—	—
KG-2	1410	1800	1	3.8:1	1	18000	—	—
KG-5	2840	3130	1	6.3:1	1	17400	1	12000
KG-501	3140	3850	14	9.5:1	4	14500	—	—
KG-570	4580	5090	13	12.1:1	2	14722	2	12000

All data is subject to change without notice



23'11" L x 7'0" W x 9'11" H
729 cm x 213 cm x 302 cm
Weight. 45.500 lbs / 20.638 kg

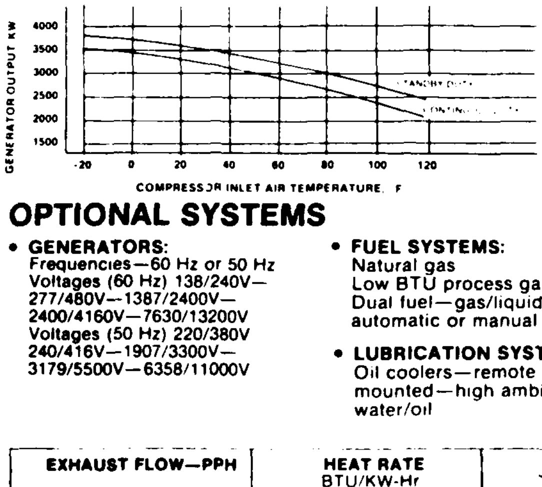
2100 to 3130 KW (2625-3912 KVA)

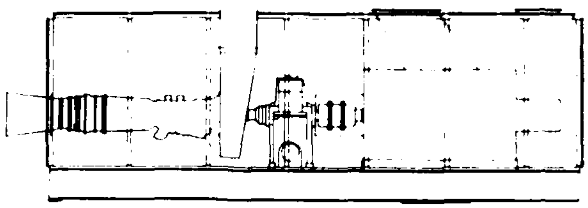
NATCO KG-5

The NATCO KG-5 gas turbine generator set incorporates the KG-5 two-shaft turbine—which is basically a growth version of the proven KG-2, with a similar radial compressor and single can tangential combustor—thus continuing the reputation for simple, rugged construction and high tolerance to fuel quality.

A single structural base carries the turbine and generator, fuel and lubrication systems. A free-standing turbine control panel houses the NATCO Turbotronic control system. A separate cubicle is furnished for optional circuit breakers.

TURBINE: KG-5 dual shaft, industrial gas turbine rated 4700 HP with radial compressor and turbine, axial power turbine, single tangential combustor, tilting pad radial and thrust bearings, flexible couplings and integral reduction and accessory gear drives.
GENERATOR: Rated 2100 to 3130 KW (2625-3912 KVA), 4160V, 0.8 power factor, brushless type exciter, static voltage regulator.





26' L x 8' W x 9'6" H
792 cm x 244 cm x 290 cm
Weight. 56.000 lbs / 25.400 kg

2750 to 3850 KW (3437-4812 KVA)

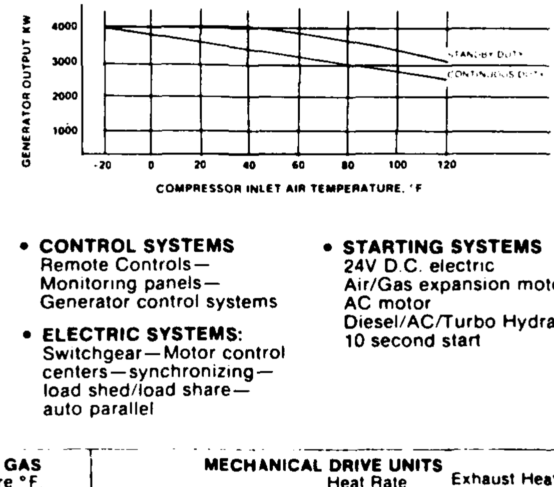
NATCO KG-501

The NATCO 501 incorporates the KG-501 industrial turbine developed from the proven Allison 501 propulsion turbine that has been in production for over 20 years.

The single-shaft version of the turbine used for generator drives has a 14-stage axial compressor, six combustion chambers in an annular combustor, and a four-stage air-cooled axial turbine.

The generator set is mounted on a one-piece structural base which contains the complete fuel, lubrication and starting systems. A free-standing control cubicle houses the NATCO Turbotronic control system.

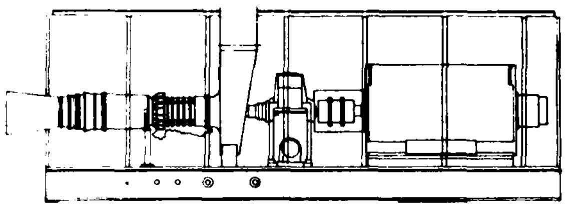
TURBINE: KG-501 single shaft, industrialized gas turbine rated 5300 HP, 14 stage axial flow compressor, 4 stage power turbine, anti-friction bearings, integral accessory gearbox and separate main gear reduction.
GENERATOR: Rated 2750-3850 KW (3437-4812 KVA), 4160V, 0.8 power factor, brushless type exciter, static voltage regulator.



OPTIONAL SYSTEMS

- **GENERATORS:**
  Frequencies—60 Hz or 50 Hz
  Voltages (60 Hz) 138/240V—277/480V—1387/2400V—2400/4160V—7630/13200V
  Voltages (50 Hz) 220/380V 240/416V—1907/3300V—3179/5500V—6358/11000V
- **FUEL SYSTEMS:**
  Natural gas
  Low BTU process gas
  Dual fuel—gas/liquid—automatic or manual
- **LUBRICATION SYSTEMS:**
  Oil coolers—remote mounted—high ambient—water/oil
- **CONTROL SYSTEMS**
  Remote Controls—
  Monitoring panels—
  Generator control systems
- **ELECTRIC SYSTEMS:**
  Switchgear—Motor control centers—synchronizing—load shed/load share—auto parallel
- **STARTING SYSTEMS**
  24V D.C. electric
  Air/Gas expansion motor
  AC motor
  Diesel/AC/Turbo Hydraulic
  10 second start

EXHAUST FLOW—PPH		HEAT RATE BTU/KW-Hr		EXHAUST GAS Temperature °F		MECHANICAL DRIVE UNITS			
Continuous	Standby	Continuous	Standby	Continuous	Standby	HP	RPM Range	Heat Rate BTU/HP/Hr	Exhaust Heat "Q" BTU/Hr x 10⁶
27.760	27.800	17.550	16.530	928	995	690	85-100%	12460	4 5
104.000	108.700	21.850	21.500	1025	1100	2000	85-100%	15350	19 0
169.800	173.000	16.830	16.580	920	975	3970	6000-12000	12040	26 5
127,500	127.800	12.850	12.070	940	1040	4460	12850-15000	8970	20 5
150.200	157.000	12.020	12.050	1080	1140	6525	6000-12000	8390	29 5



26' L x 8' W x 9'6" H
792 cm x 244 cm x 290 cm
Weight: 60,000 lbs / 27,210 kg

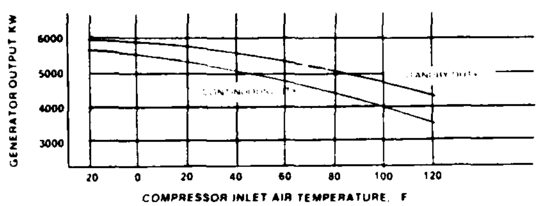
4000 to 5090 KW (5000-6362 KVA)

NATCO KG-570

The NATCO KG-570 is the latest and most powerful addition to the NATCO family of gas turbine generator sets.

It incorporates the Allison 570 gas turbine, the most efficient in its class because of its thermodynamic design and material selection. Versions of the NATCO KG-570 are available as mechanical drive units and compressor sets. Each unit is self-contained on its structural steel base except for a free-standing control cubicle.

TURBINE: KG-570 dual shaft industrial gas turbine, gas generator has 13 stage axial flow compressor and two stage air cooled turbine. Two stage power turbine is gas coupled to the gas generator. Integral accessory gearbox and separate main gear reduction.
GENERATOR: Rated 4000 to 5090 KW (5000-6362 KVA), 13.2KV, 0.8 power factor, brushless type exciter, static voltage regulator.



- **INLET AIR SYSTEM:** Filters—residential, industrial, marine environment or desert atmosphere. Silencers—residential or industrial
- **EXHAUST GAS SYSTEMS:** Expansion joints—diffusers—elbows, ducting. Silencers—residential or industrial
- **HEAT RECOVERY SYSTEMS:** Hot water, high pressure/low pressure steam or process heat
- **DC SYSTEMS:** For control power and/or starting
- **ENCLOSURES:** Indoor—Outdoor—Walk-in modules. Fire/gas detection systems. Fire suppression systems
- **PAINTING AND COATINGS:** To meet special requirements of color and or environmental conditions
- **SPECIAL TOOLS:** For handling or maintenance
- **SPECIAL PRODUCTS:** Single lift structures for complete energy systems—Offskid fuel systems—Starting air compressors and receivers

CONTROL CHARACTERISTICS

- Voltage regulation (steady state) $\pm 0.5\%$.
- Voltage regulation (0-100% load) $\pm 2\%$ max.
- Transit voltage deviation $\pm 25\%$ (no load to full load).
- Transit recovery to $\pm 5\%$ in 1 second.
- Voltage adjustment range $\pm 10\%$.
- TIF (1960 weighing) 150 or less.
- Maximum total harmonic content not to exceed 5%.
- Deviation factor (open circuit) 10% line to line/line to neutral
- Short circuit capacity 300% rated KVA for 10 seconds 3 phase symmetrical fault
- Compliance with NEMA Standard MG1-1972

TOTAL ENERGY: COGENERATION

The gas turbine is well suited for in-plant power generation systems that provide low or high pressure steam, hot water or process heat additional to the electrical energy derived from burning liquid or gaseous fuels.

We are entering a period in our economy when utilities are looking with favor on in-plant generation systems that can feed the utility grid with their excess electrical energy. There are favorable dollars-and-cents reasons to develop a co-generation system if you have a process that can use the by-products of a gas turbine generator—heat in the form of hot air, hot water or steam.

NATCO has the experience and know-how to work with you in the design of these systems, and to take *full responsibility for providing all* system components. This can include fuel treating systems, fuel gas compressors if required, steam generators, economizers, steam turbines, bypass and isolation valves, etc.

Developing a cogeneration system that operates at the highest possible efficiency requires a careful selection and matching of components. It also requires a high level of communication between the supplier and end user to assure that the trade-offs made in any system design are to the benefit of the user.

When you think of the advantages of cogeneration, think of the advantages of working with NATCO. With the wide range of turbines available, we offer the flexibility to meet your exacting requirements.

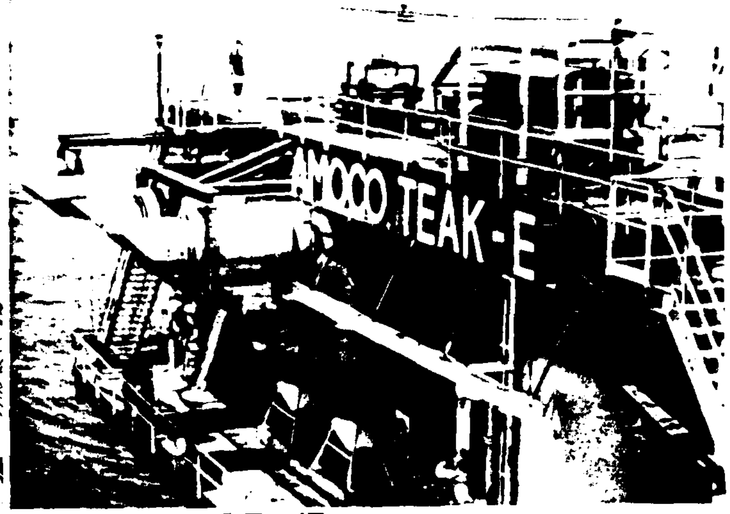
MECHANICAL DRIVE UNITS

NATCO turbines have been adapted for mechanical drives and have successfully operated as prime movers for cargo pumps, fire pumps, gas compressors and blowers.

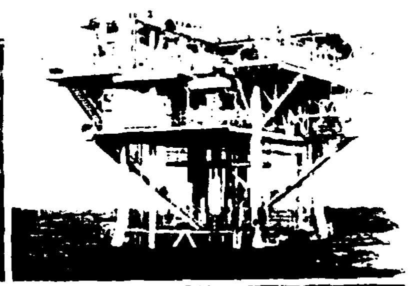
The NATCO KG-5 and NATCO KG-570 are particularly suited to these applications because of their favorable speed-torque characteristics. In a number of selected applications, the single-shaft NATCO turbines have proven themselves as reliable power sources.

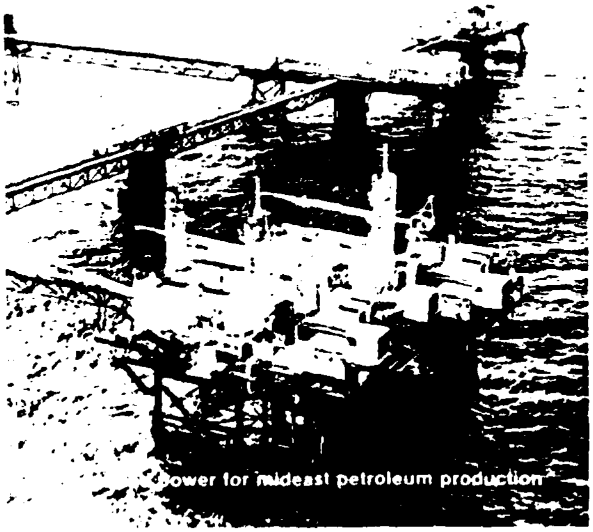
NATCO GAS TURBINE POWER

TYPICAL APPLICATIONS



...CO KG-2 supporting ... communications center

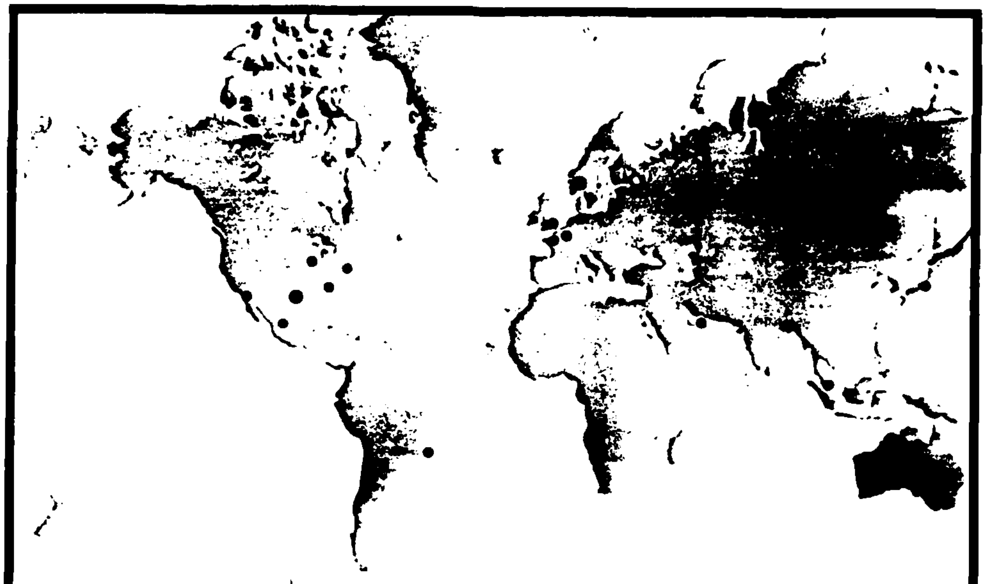




...ower for mideast petroleum production

Continuous power generation w/waste heat boilers for ... barrel storage barge

NATCO...GAS TURBINE POWER



INTERNATIONAL SALES & SERVICE

NORTH AMERICAN TURBINE CORPORATION

HEADQUARTERS
11500 Charles Street • P.O. Box 40510
(713) 466-6200 • Telex: 762-315
Houston, Texas 77040

NORTHEAST:
135 Fort Lee Road
Leonia, N.J. 07605
(201) 461-8194
Telex: 135-115

NORTH CENTRAL:
2300 E. Higgins Rd., Suite 200-1
Elk Grove Village, ILL. 60007
(312) 437-8430

SOUTHEAST:
2022 Powers Ferry Road
Suite 180
Atlanta, GA 30339
(404) 953-1438

WESTERN:
189 Viking Avenue
Brea, Calif. 92621
(714) 529-0114
Telex: 678-376

KONGSBERG GAS TURBINES & POWER SYSTEMS

Kongsberg • London • Paris • Frankfurt • Dubai • Singapore

Tokyo • Rio de Janiero

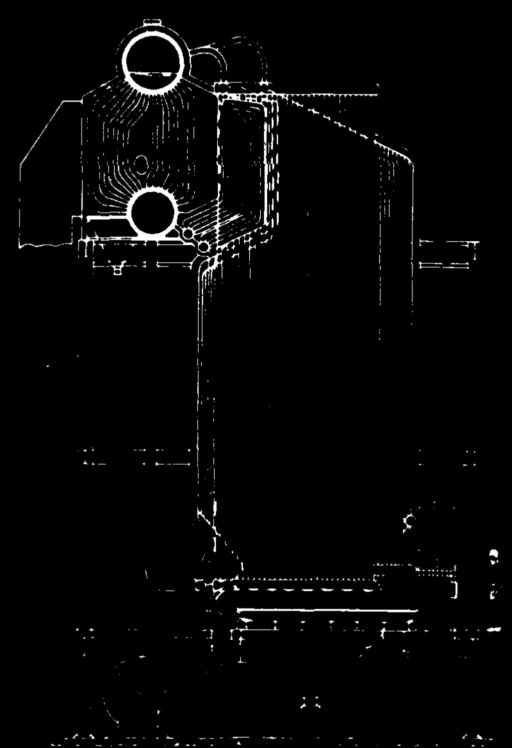
NORTH AMERICAN TURBINE CORPORATION

HOUSTON, TEXAS U.S.A. / DIVISION OF KONGSBERG NORTH AMERICA

MB-201 11/80 5000

APPENDIX C

Direct Combustion
Cogeneration Literature



Performance–the Riley Standard

The Riley Shop Assembled Modular Boiler

RILEY STOKER

A Subsidiary of United States Riley Corporation

C-2

Introducing the Riley Shop Assembled Modular Boiler

UP TO 150,000 POUNDS OF STEAM PER HOUR FIRED BY COAL

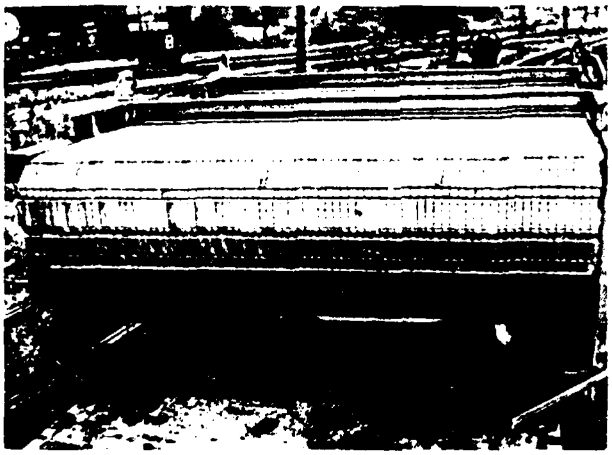
Riley took the best features of the package boiler, teamed them with a spreader stoker and came up with the Shop Assembled Modular Boiler. The result is a unique coal-fired "packaged modular" design available in twelve incremental sizes from 40,000 to 150,000 pounds of steam per hour. Pressures up to 1650 psig design are available.

The basic "building blocks" are the boiler bank section, the superheater, the furnace section and the stoker. While the modular approach to boiler fabrication is relatively new, the Shop Assembled Modular Boiler actually is a re-arrangement of time-proven concepts. It has a maximum of shop-assembled components so field erection time is held to a minimum. There are no heat transfer unknowns. Riley guarantees performance with the same confidence it has for its other field-erected steam generators.

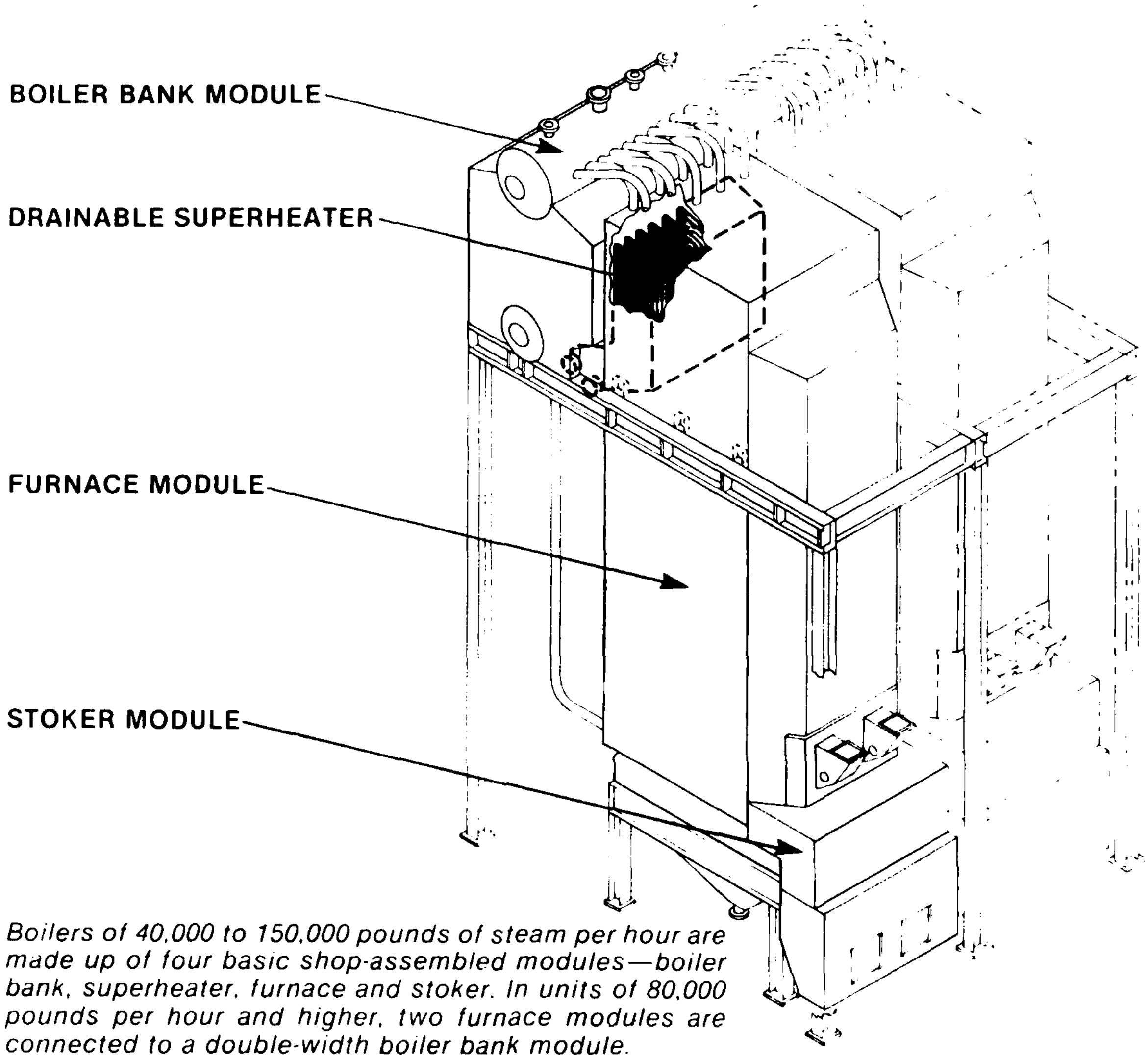
Shop assembly is less expensive and allows close quality control. Modules fit together better and quicker, requiring fewer man-hours of field labor. This adds up to cost savings, making the Riley Shop Assembled Modular Boiler the first choice for coal-fired industrial requirements.

Contact the nearest Riley Sales Engineer for details.

Riley traveling grate stoker on rail car ready for shipment.



The furnace module is entirely welded wall construction. Larger modules have bias corners to provide clearance during rail shipment.



Boilers of 40,000 to 150,000 pounds of steam per hour are made up of four basic shop-assembled modules—boiler bank, superheater, furnace and stoker. In units of 80,000 pounds per hour and higher, two furnace modules are connected to a double-width boiler bank module.

The Riley Shop Assembled Modular Boiler

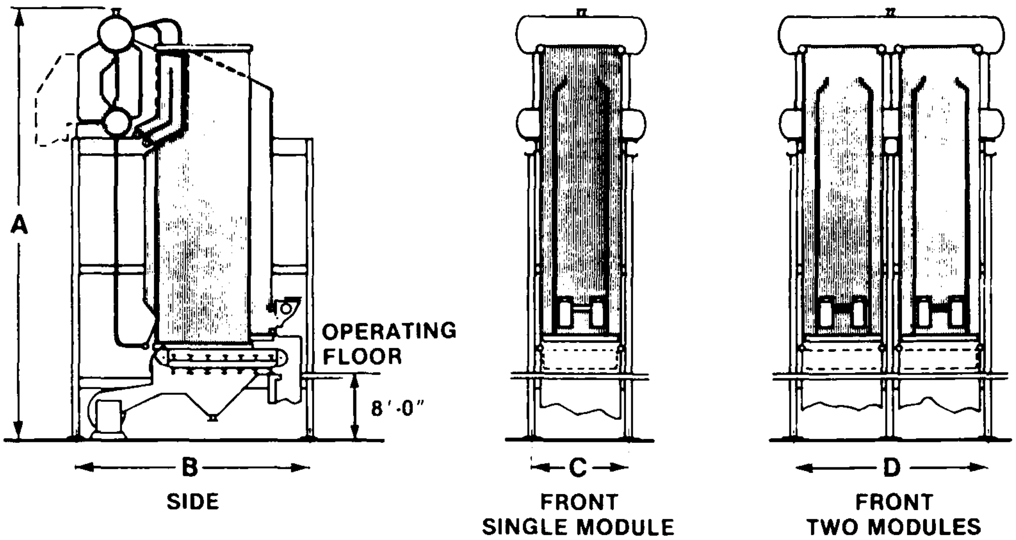
Shortens lead time from order to operation

Cuts field labor costs

Reduces required structural steel

Lowers maintenance cost with welded wall construction

Costs less than field erected unit



SINGLE FURNACE MODULE ARRANGEMENT

SIZE	40	45	50	60	70	75
NOMINAL CAPACITY POUNDS STEAM PER HOUR	40,000	45,000	50,000	60,000	70,000	75,000
DIMENSION A*	44'-7"	44'-7"	44'-7"	48'-10"	51'-10"	51'-10"
DIMENSION B	26'-6"	26'-6"	26'-6"	28'-6"	28'-3"	28'-3"
DIMENSION C	9'-2"	10'-2"	11'-2"	11'-2"	12'-2"	13'-2"

TWO FURNACE MODULE ARRANGEMENT

SIZE	80	90	100	120	140	150
NOMINAL CAPACITY POUNDS STEAM PER HOUR	80,000	90,000	100,000	120,000	140,000	150,000
DIMENSIONS "A"* AND "B" ARE THE SAME AS SINGLE MODULE ABOVE						
DIMENSION D	18'-4"	20'-4"	22'-4"	22'-4"	24'-4"	26'-4"

*HEIGHT SHOWN IS NOMINAL, AND MAY VARY DEPENDING ON AUXILIARY FIRING OR USE OF HIGH SLAGGING COALS

RILEY STOKER

RILEY STOKER CORPORATION
POST OFFICE BOX 547, WORCESTER, MASS. 01613
A Subsidiary of United States Riley Corporation

11-80SAM5M-L

APPENDIX D

Correspondence with Candidate Installations

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS ARNOLD ENGINEERING DEVELOPMENT CENTER (AFSC)
ARNOLD AIR FORCE STATION, TENNESSEE 37389

1 2 JUN 1980

DEE

Arnold AFS Fuel Consumption Data

Ultrasystems, Inc
ATTN: Mr Desmond Bond
7926 Jones Branch Drive
Suite 888
McLean, Virginia 22102

Enclosed is fuel consumption data for Arnold AFS (our telecon, 4 June 80). Attachment 1 shows monthly natural gas and fuel consumption data for steam plants A and B. Natural gas is the primary fuel with fuel oil being used primarily during gas curtailments. Attachment 2 shows total (basewide) consumption of electricity and fuels for FY 79 and FY 80 to date. This includes not only the steam plant, but also other heaters located in the test facilities. Fuel oil is mostly #2 with some waste oil burned occasionally. Please let me know if you need more information.

Edmund Stern

EDMUND H. STERN 2D LT, USAF
Directorate of Engineering Support
Deputy for Facility Resources

2 Atchs
1. Steam Plant Fuel Consumption
2. Total Fuel Consumption

6 June 80

Steam Plant Fuel Consumption Data
Arnold AFS TN 1/79 - 5/80

Month	A - Plant		B - Plant	
	Natural Gas (000's ft^3)	Fuel Oil (gals.)	Natural Gas (000's ft^3)	Fuel Oil (gals.)
1/79	42,639	310,964	409	5,600
2/79	47,347	154,851	1,051	2,800
3/79	57,203	13,350	1,649	—
4/79	49,718	—*	888	—
5/79	32,397	—	2,936	—
6/79	22,126	—	14,811	—
7/79	33,757	—	1,649	—
8/79	38,865	—	4,290	—
9/79	38,407	9,812	3,931	20,800
10/79	45,176	31,961	601	—
11/79	59,321	10,509	1,818	—
12/79	61,999	15,300	1,537	—
1/80	60,373	35,[illegible]00	2,756	—
2/80	57,117	63,450	1,567	—
3/80	58,239	18,450	2,288	—
4/80	44,661	—	2,095	—
5/80	29,809	27,000**	9,644	—

* None used

** Used during a plant modification

Atch 1

ENERGY CONSUMPTION FY1979 Arnold AFS

ERGY / NTH	ELECT MWH	11.6 ELECT MBTU	NATURAL GAS MCF	1.031 NATURAL GAS MBTU	PROPANE GAL	.09590 PROPANE MBTU	FUEL OIL GAL	.138690 FUEL OIL MBTU	TOTAL MBTU	% CHANGE FY 75
OC	36,030	417,948	54,701.5	56,397.2	0	0	42	5.8	474,351	-33.95
NO	28,440	329,904	52,351.8	53,974.7	3915	372	0	0	858,602 384,251	-41.49 -48.73
DE	24,000	278,400	66,776.6	68,840.5	5925	563	35,2[illegible]	4,893	1,211,299 352,6[illegible]	-42.05 -16.52
JAN	42,850	497,060	61,949.1	63,869.5	8250	784	267,130	37,047	1,810,[illegible] 5[illegible]	-[illegible] -7.15
FEB	30,410	352,756	58,686.5	60,505.8	50	4.8	190,63[illegible]	26,4[illegible]	2,2[illegible] 4[illegible]	-[illegible] -9.5[illegible]
MAR	37,700	4[illegible]	74,025.9	76,321.0	20	1.9	[illegible]	[illegible]	2,770,[illegible] [illegible]	-[illegible] [illegible]
APR	33,840	392,544	61,340.3	63,241.8	50	4.8	294	41	3,2[illegible] 455,[illegible]	-[illegible] -[illegible]
MAY	38,040	441,264	50,857.3	52,435.9	375	35.6	42	5.8	3,740,480 493,741	-27.87 -32.0
JUN	39,400	457,040	50,697.4	52,269.0	0	0	42	5.8	4,249,795 509,315	-27.29 [illegible]
JUL	40,200	466,320	52,815.1	54,452.4	1100	104.5	0	0	4,770,672 520,877	-26.41 -23.67
AUG	50,760	588,816	63,434.8	65,401.3	150	14.3	0	0	5,424,904 654,232	-25.49 -12.21
SEP	43,350	502,[illegible]	65,895.[illegible]	67,938.[illegible]	80	7.6	30,613	4,2[illegible]	5,777,[illegible] 575,[illegible]	-[illegible] -[illegible]
TOTAL	[illegible]	5[illegible]	71,3[illegible]	735,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

D-4

Atch 2

ENERGY CONSUMPTION FY 80

Y	ELECT MWH	11.6 ELECT MBTU	NATURAL GAS MCF	1.031 NATURAL GAS MBTU	PROPANE GAL	.09550 PROPANE MBTU	FUEL OIL GAL	.138690 FUEL OIL MBTU	TOTAL MBTU	% CHANGE FY75/79
OCT	31220	362,152	55,589.7	57,313	0	0	31,963	4433	423,88[illegible]	-41/-11
NOV	31200	361,920	71,344.3	73,556	0	0	10,087	1399	360,77[illegible] 436,875	-42/+1[illegible]
DEC	28620	331,993	70,057.2	72,229	73	7	19,050	2642	[illegible] 406,8[illegible]	-37/+15
JAN	40180	466,088	75,806.0	78,156	52	5	17,499	2427	[illegible] 546,[illegible]	-15/-9
FEB	43560	505,296	62,841.9	64,790	126	12	63,451	[illegible]	[illegible]	+19/[illegible]
	32320	374,912	67,372.4	69,461	146	[illegible]	18,451	[illegible]	[illegible]	[illegible]
APRIL	43390	[illegible]	60,375.4	62,247	1005	[illegible]	0	[illegible]	[illegible]	[illegible]
MAY	[illegible]	500,656	55,004.8	[illegible]	9748	[illegible]	27,003	[illegible]	562,042	23/+14

Atch 2 (cont'd)

DEPARTMENT OF THE AIR FORCE
56TH COMBAT SUPPORT SQUADRON (TAC)
AVON PARK AIR FORCE RANGE, FLORIDA 33825

11 June 1980

REPLY TO ATTN OF: DE

SUBJECT: Fuels Consumption for this Installation

TO: Ultra Systems, Inc.
4926 Jones Branch Dr.
Suite 88
McLean, VA 22102

1. Enclosed please find data you requested on fuels consumption for this installation.

2. The period of use is FY 79. Please note that one month had no propane purchase. Also in fuel oil, the records are for the year and not available by month.

Electricity (KWHs)

OCT	266,722	APR	191,307
NOV	196,167	MAY	212,560
DEC	142,472	JUN	252,528
JAN	241,820	JUL	276,777
FEB	253,877	AUG	278,646
MAR	131,317	SEP	272,437

3. Propane LP Gas (Cu. Ft.)

OCT	228	APR	--
NOV	265	MAY	893
DEC	189	JUN	350
JAN	173	JUL	137
FEB	343	AUG	299
MAR	111	SEP	181

4. Fuel Oil (Gals)

2500 for year
Only one facility utilizes this fuel for a hot water boiler.

5. The above information is given to you in the hope that it will fulfill your needs. Should you require additional facts, do not hesitate to contact us.

Harrie Bateman

HARRIE BATEMAN, GS-11
Range Civil Engineer

Readiness is our Profession

Mr. Bond:

Per your 4 Jun 80 conversation with

Mr. Louis Landry, 2 CES/DEE,

Barksdale.

Jean Lutz
Secretary

recd 6/16/80

Utility Consumption (Base & MFH & Hospital)

		Elect (KWH)	Gas (1000 CF)	Water (1000 Gal)	Sewage (1000 Gal)	Fuel Oil (Gals)
FY 75	MFP-1	53,694,991	245,773	157,027		
	MFP-8	1,871,440	27,354	12,767		
	MFH	17,803,273	116,831	221,295		
	FY Totals	73,369,704	389,958	391,089		
	Unit Cost	0.01082	0.8232	0.24675		
FY 76	MFP-1	50,468,986	233,064	165,898		
	MFP-8	1,784,839	28,306	12,133		
	MFH	17,958,806	107,686	238,263		
	FY Totals	70,212,631	369,056	416,294		
	Unit Cost	0.1257	0.9027	0.24627		
FY 77	MFP-1	50,022,905	267,381	165,599		
	MFP-8	5,277,302	19,247	15,569		
	MFH	18,911,813	122,187	219,320		
	FY Totals	74,212,020	408,815	400,488		
	Unit Cost	0.1487	1.145	0.30001		
FY 78	MFP-1	52,036,518	274,115	157,315		
	MFP-8	5,702,112	27,831	22,447		
	MFH	18,582,590	124,259	213,548		
	FY Totals	76,321,220	426,205	393,310		
	Unit Cost	0.1728	1.370	0.3000		
FY 79	MFP-1	51,128,269	254,456	155,282	112,157	26,357
	MFP-8	5,438,232	29,834	15,941	11,040	328,000
	MFH	15.612,179	114,920	205,124	154,907	-
	FY Totals	72,178,680	399,210	376,347	278,104	354,357
	Unit Cost	0.1737	1.684	0.2998	0.192	-

NOTE: MFP-1 (Base Only)
MFP-8 (Hospital)
MFH (Military Family Housing)

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS ARMAMENT DIVISION (AFSC)
EGLIN AIR FORCE BASE, FLORIDA 32542

16 JUN 1980

REPLY TO ATTN OF: DEEE (Mr. Schultz, 882-2866)

SUBJECT: Advanced Bioenergy Systems for Air Force Facilities (FY 80 R&D Project for HQ AFESC Administered by the US Army Facilities Engineering Support Agency)

TO: Mr. Desmond Bond
Ultra Systems, Inc.
7926 Jones Branch Drive
Suite 888
McLean VA 22102

1. The following background information is forwarded for your use as requested in your telephone conversation with Mr. Fred Schultz (AD/DEEE) on 4 June 1980:

a. 1979 Electrical Consumption

b. 1979 Natural Gas Consumption

c. 1979 Water Consumption

d. 1979 Propane Consumption

e. 1979 Fuel Oil Consumption

f. Environmental Assessment for Central Heat Generating Plants, FY 80 MCP, Eglin AFB

g. Appendices to Environmental Assessment for Central Heat Generating Plants, FY 80 MCP, Eglin AFB

h. MCP Project Data

(1) FY 82 Central Steam Plant - Wood-Fired, Field 3

(2) FY 82 Refuse-Fired Central Energy Plant

(3) FY 80 Central Steam Plant - Main Base

(4) FY 80 Central Steam Plant(s) - Wood-Fired (three plants: Field 3, Main Base Hospital, and Officers' Open Mess Area)

2. It is our understanding that you are planning a visit to Eglin during the month of July. During the week prior to your visit, we ask that you coordinate your proposed visit with either Mr. Schultz or the Chief of the Engineering/Technical Design Branch, Mr. Pelham (904-882-3475/4279).

Paul R. Eyrich, Jr.

PAUL R. EYRICH, JR.
Chief, Engrg & Envmtl Planning Div
Directorate of Civil Engineering

4 Atch (listed on next page)

1. FY 79 Utility Consumption Figures
wd 2. Environmental Assessment
wd 3. Appendices to Environmental Assessment
wd 4. MCP Project Data

Cy to: HQ AFESC/RDVA (Mr. Stephen Hathaway) wo/Atch
Tyndall AFB FL 32403

ELECTRICITY 1979

	Consumption (KWH)	Cost
JAN	18,479,391	638,869.86
FEB	15,609,618	563,984.01
MAR	16,367,715	537,202.30
APR	17,714,858	601,270.67
MAY	21,497,804	700,052.06
JUN	22,726,142	724,516.92
JUL	28,385,908	921,048.53
AUG	25,992,338	820,261.29
SEP	23,958,199	776,440.54
OCT	19,873,396	579,806.67
NOV	15,672,449	562,114.68
DEC	16,096,612	656,449.08
TOTALS	242,373,830 KWH	$ 8,081,936.61

NATURAL GAS 1979

	Consumption (MCF)	Cost
JAN	142,027	311,460.52
FEB	109,462	242,725.01
MAR	70,305	162,347.55
APR	32,945	85,856.69
MAY	32,955	86,038.80
JUN	28,424	76,523.65
JUL	27,790	95,026.41
AUG	28,229	95,798.69
SEP	28,630	97,391.40
OCT	36,730	83,781.27
NOV	42,690	93,747.64
DEC	95,769	209,990.09
TOTALS	675,956 MCF	$ 1,640,687.72

Jan 79 – Dec 79

WATER

Month	Consumption (KGAL)	Cost
JAN	84,147	32,931.00
FEB	69,179	27,081.00
MAR	80,430	31,476.00
APR	108,659	42,535.00
MAY	161,260	63,189.00
JUN	189,511	74,165.00
JUL	127,375	49,848.00
AUG	117,921	46,148.00
SEPT	95,823	37,500.00
OCT	103,831	40,634.00
NOV	89,017	34,837.00
DEC	73,471	28,753.00
TOTAL	1,300,724 KGals.	$ 509,017

PROPANE Jan 79 - Dec 79

Month	Consumption	Cost
JAN	474.1	1989.00
FEB	36.0	166
MAR	846.0	3,230
APR	789.9	3,313.05
MAY	203.0	786.00
JUN	37.0	156.00
JUL	291.0	1336.00
AUG	37.0	156.00
SEPT	95.0	398.00
OCT	7.4	31.20
NOV	0	0
DEC	0	0
TOTAL	2,816.4 MBTU	$ 11,561.25

Fuel Oil

Month	Consumption (MBTU)	Cost
JAN	5,111 0	16,660.00
FEB	4874.0	15,953.00
MAR	3,906.0	12,498.00
APR	842.0	2,767.00
MAY	2624.0	8,621.00
JUN	1477 0	727.0
JUL	548	766.36
AUG	1077.0	3,539.0
SEP	555.0	1823.0
OCT	524.6	2,603.6
NOV	6872.2	34,363.70
DEC	2579.9	12,903.90
TOTAL	30,597.5 MBTU	$ 113,245.56

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE ENGINEERING AND SERVICES CENTER
TYNDALL AIR FORCE BASE FL 32403

13 JUN 1980

Mr Desmond Bond
Ultrasystems, Inc.
7926 Jones Branch Drive
McLean VA 22101

Dear Mr Bond

As I discussed with you on 6 June, I am forwarding FY79 facility energy consumption data for Eglin, Tyndall, Arnold, Barksdale and MacDill Air Force Bases to support your bioenergy study being performed for us through the U S Army Facilities Engineering Support Agency (FESA). I have informed Mr Sandy Helms at FESA of this transmittal and have sent copies of the same data to him.

If you have any questions regarding these data, please do not hesitate to contact either Mr Helms at FESA or me at the above address or at (904) 283-4114.

Sincerely

Stephen A. Hathaway

STEPHEN A. HATHAWAY
Project Officer

1 Atch
Facility Energy Data Sheets

AD-A117 084 ULTRASYSTEMS INC FAIRFAX VA F/G 10/1
ADVANCED BIO-ENERGY SYSTEMS FOR AIR FORCE INSTALLATIONS.(U)
OCT 81 W J HUFF, D H BOND DACA31-80-D-0020
UNCLASSIFIED FESA-T-2110 NL

2 OF 2
AD
A117084

END
DATE
FILMED
8 82
DTIC

21 MAY 80 AS OF 79 273 (FY79) ANNUAL ENERGY CONSUMPTION REPORT

MAJCOM	COAL	ELECTRIC	FUEL OIL	NAT GAS	PROPANE	STM/HW	TOTAL MBTU	MBTU/SQFT	SQUARE FEET
AAC	2,196,265	4,176	1,802,708	2,865,124	167	154,573	7,023,013	.4003	17,540,368
CLSBS	0	24,974	32,387	0	0	0	57,361	.0370	1,546,426
AFLC	2,730,288	13,019,212	735,057	7,306,131	7,138	0	23,797,826	.3040	78,269,216
AFRES	811	522,751	507,345	204,282	576	0	1,235,765	.2347	5,263,566
AFSC	0	12,801,541	1,473,749	3,699,450	17,536	0	17,992,276	.4865	36,975,613
ANG	382,616	2,973,526	1,010,914	1,225,891	17,085	6,877	5,616,909	.2055	27,321,776
ATC	968,548	10,098,238	338,478	5,816,706	11,952	0	17,233,922	.2667	64,595,106
MAC	16,786	11,425,977	4,920,119	4,070,553	91,882	342,685	20,868,002	.2628	79,404,552
PACAF	0	7,904,017	3,600,831	0	20,359	11,010	11,536,217	.2202	52,379,905
SAC	2,808,200	21,652,700	9,579,257	9,522,537	73,824	0	43,636,518	.3269	133,451,112
TAC	401,802	14,550,725	3,405,757	3,757,460	41,698	0	22,157,442	.2672	82,916,356
USAFA	0	917,280	2,508	1,138,044	3,973	0	2,061,805	.2800	7,362,580
USAFE	3,171,376	6,450,039	7,055,366	183,320	20,455	6,828	16,887,384	.2560	65,956,177
TOTAL	12,676,692	102,345,156	34,464,476	39,789,498	306,645	521,973	190,104,440	.2911	652,982,753

MAJCOM (MAJOR COMMAND)

AAC	ALASKAN AIR COMMAND
CLSBS	CLOSED BASES (ONLY 1 BASE; KARAMUSEL, TURKEY)
AFLC	AIR FORCE LOGISTICS COMMAND
AFRES	AIR FORCE RESERVE
AFSC	AIR FORCE SYSTEMS COMMAND
ANG	AIR NATIONAL GUARD
ATC	AIR TRAINING COMMAND
MAC	MILITARY AIRLIFT COMMAND
PACAF	PACIFIC AIR FORCE
SAC	STRATEGIC AIR COMMAND
TAC	TACTICAL AIR COMMAND
USAFA	US AIR FORCE ACADEMY
USAFE	[illegible] AIR FORCE EUROPE

MONTH	COAL	ELECTRIC	FUEL OIL	NAT GAS	PROPANE	STM/HW	TOTAL MBTU	MBTU/SQFT	SQUARE FEET
OCT 1978	0	65,946	2,074	9,588	0	0	77,608	.0189	4,088,498
NOV	0	61,086	1,189	12,009	0	0	74,283	.0181	4,088,498
DEC	0	57,327	2,458	25,286	0	0	85,071	.0208	4,088,498
JAN	0	59,752	716	44,850	0	0	105,318	.0257	4,088,498
FEB	0	83,939	1,171	14,209	0	0	99,319	.0242	4,088,498
MAR	0	49,116	2,436	22,949	0	0	74,501	.0182	4,088,498
APR	0	59,612	716	10,715	0	0	71,043	.0173	4,088,498
MAY	0	73,515	743	7,742	0	0	82,400	.0201	4,088,498
JUN	0	113,459	1,170	6,111	0	0	121,170	.0296	4,088,498
JUL		92,223	1,146	5,987	0	0	99,355	.0243	4,088,498
AUG	0	98,008	3,498	6,259	0	0	107,765	.0263	4,088,498
SEP 1979	0	94,359	2,177	6,302	0	0	102,868	.0251	4,088,498
TOTAL	0	880,699	19,995	192,007	0	0	1,100,701	.2692	4,088,498

MONTH	COAL	ELECTRIC	FUEL OIL	NAT GAS	PROPANE	STM/HW	TOTAL MBTU	MBTU/SQFT	SQUARE FEET
OCT 1978	0	91,469	7,053	6,179	25	0	105,546	.0247	4,259,891
NOV	0	72,291	7,793	6,078	0	0	86,762	.0203	4,259,891
DEC	0	79,228	9,565	9,043	18	0	97,854	.0229	4,259,891
JAN	0	65,726	6,419	17,269	60	0	89,474	.0210	4,259,891
FEB	0	60,010	7,153	19,532	85	0	87,380	.0205	4,259,891
MAR	0	58,313	11,671	11,119	33	0	81,336	.0190	4,259,891
APR	0	66,611	5,604	6,946	13	0	82,774	.0194	4,259,891
MAY	0	77,947	7,647	6,590	18	0	92,242	.0216	4,259,891
JUN	0	87,719	8,067	6,571	11	0	102,368	.0240	4,259,891
JUL	0	103,217	6,706	4,949	0	0	114,872	.0269	4,259,891
AUG	0	96,061	9,985	5,987	17	0	114,670	.0269	4,259,891
SEP 1979	0	96,063	6,740	5,494	0	0	108,307	.0254	4,259,891
TOTAL	0	960,155	94,603	109,347	280	0	1,163,585	.2731	4,259,891
		* 32492		* 444					AVON 4.3%

D-17

*COST REPORT / O&M ONLY, EXCL-HOUSING

NOTE: AVON PARK REPORTED WITH MACDILL. ESTIMATE AVON PARK PORTION BASED ON ITS 4.3% SHARE OF TOTAL SQUARE FOOTAGE REPORTED HEREIN.

MONTH	COAL	ELECTRIC	FUEL OIL	NAT GAS	PROPANE	STM/HW	TOTAL MBTU	MBTU/SQFT	SQUARE FEET
OCT 1978	0	70,830	0	23,863	0	0	94,693	.0195	4,844,963
NOV	0	57,269	0	31,258	0	0	88,527	.0182	4,844,963
DEC	0	55,251	0	60,164	0	0	115,415	.0238	4,844,963
JAN	0	64,656	0	96,577	0	0	159,533	.0329	4,844,963
FEB	0	55,680	0	63,141	0	0	118,821	.0245	4,844,963
MAR	0	49,602	0	35,955	0	0	85,557	.0176	4,844,963
APR	0	52,502	0	21,201	0	0	73,703	.0152	4,844,963
MAY	0	66,555	0	17,089	0	0	84,644	.0174	4,844,963
JUN	0	82,244	0	13,459	0	0	95,702	.0197	4,844,963
JUL	0	99,748	0	11,599	0	0	111,347	.0229	4,844,963
AUG	0	92,974	0	11,939	0	0	104,912	.0216	4,844,963
SEP 1979	0	87,928	0	10,067	0	0	97,995	.0202	4,844,963
TOTAL	0	831,639	0	399,210	0	0	1,230,849	.2540	4,844,963

ENERGY CONSUMPTION REPORT

MONTH	COAL	ELECTRIC	FUEL OIL	NAT GAS	PROPANE	STM/HW	TOTAL MBTU	MBTU/SQFT	SQUARE FEET
OCT 1978	0	241,547	4,468	36,730	426	0	283,171	.0293	9,657,496
NOV	0	181,795	1,311	42,690	49	0	225,845	.0233	9,657,496
DEC	0	191,574	1,310	95,769	243	0	288,896	.0299	9,657,496
JAN	0	221,096	5,111	142,027	474	0	368,708	.0381	9,657,496
FEB	0	186,516	4,874	109,462	36	0	300,888	.0311	9,657,496
MAR	0	200,014	3,906	70,305	846	0	275,076	.0284	9,657,496
APR	0	189,416	842	31,720	790	0	222,768	.0230	9,657,496
MAY	0	[illegible]	2,624	32,091	203	0	263,436	.0272	9,657,496
JUN	0	23[illegible],431	1,477	27,692	37	0	265,637	.0275	9,657,496
JUL	0	302,319	2,142	27,100	291	0	331,918	.0343	9,657,496
AUG	0	272,322	1,077	27,405	37	0	300,901	.0311	9,657,496
SEP 1979	0	[illegible]	555	27,846	95	0	263,408	.0272	9,657,496
TOTAL	0	[illegible]	29,697	670,963	3,527	0	3,390,654	.3510	9,657,496

MONTH	COAL	ELECTRIC	FUEL OIL	NAT GAS	PROPANE	STM/HW	TOTAL MBTU	MBTU/SQFT	SQUARE FEET
OCT 1978	0	417,948	6	56,397	0	0	474,351	.2414	1,964,267
NOV	0	[illegible]	0	53,975	372	0	384,251	.1956	1,964,267
DEC	0	27?,400	4,093	68,841	563	0	352,697	.1795	1,964,267
JAN	0	497,060	37,047	63,870	784	0	598,761	.3048	1,964,267
FEB	0	352,756	20,440	60,506	5	0	439,707	.2238	1,964,267
MAR	0	460,520	4,287	76,331	2	0	541,140	.2754	1,964,267
APR	0	[illegible]	41	63,242	5	0	455,832	.2320	1,964,267
MAY	0	[illegible]	6	52,436	36	0	493,742	.2513	1,964,267
JUN	0	457,040	6	52,269	0	0	509,315	.2592	1,964,267
JUL	0	466,320	0	54,452	106	0	520,878	.2651	1,964,267
AUG	0	[illegible]	0	65,401	14	0	654,231	.3330	1,964,267
SEP 1979	0	[illegible]	4,246	67,939	8	0	575,053	.2927	1,964,267
TOTAL	0	5,185,[illegible]	70,972	735,659	1,895	0	5,999,958	3.0545	1,964,267

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– 8